PALÆONTOGRAPHICAL SOCIETY.

VOL. XXXIX.

EOCENE FLORA.

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(GYMNOSPERMÆ.)

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VOLUME XXXIX.

CONTAINING

ISSUED FOR 1885.

JANUARY, 1886.

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AND

I. A CATALOGUE OF THE WORKS ALREADY PUBLISHED;

II. A CLASSIFIED LIST OF THE MONOGRAPHS COMPLETED, IN COURSE OF PUBLICATION, AND IN PREPARATION, WITH THE NAMES OF THEIR RESPECTIVE AUTHORS;

III. THE DATES OF ISSUE OF THE ANNUAL VOLUMES;

IV. A GENERAL SUMMARY, SHOWING THE NUMBER OF THE PAGES, PLATES, FIGURES, AND SPECIES IN EACH MONOGRAPH;

V. A STRATIGRAPHICAL LIST OF THE BRITISH FOSSILS FIGURED AND DESCRIBED IN THE YEARLY VOLUMES.

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§ I. CATALOGUE OF WORKS

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Showing the Order *of publication; the* Years *during which the Society has been in operation; and the* Contents *of each yearly Volume.*

Vol. I. Issued for the Year 1847		The Crag Mollusca, Part I, Univalves, by Mr. S. V. Wood, 21 plates.
„ II. „	1848	The Reptilia of the London Clay, Vol. I, Part I, Chelonia, &c., by Profs. Owen and Bell, 38 plates. The Eocene Mollusca, Part I, Cephalopoda, by Mr. F. E. Edwards, 9 plates.
„ III.* „	1849	The Entomostraca of the Cretaceous Formations, by Mr. T. R. Jones, 7 plates. The Permian Fossils, by Prof. Wm. King, 29 plates. The Reptilia of the London Clay, Vol. I, Part II, Crocodilia and Ophidia, &c., by Prof. Owen, 18 plates. The Fossil Corals, Part I, Crag, London Clay, Cretaceous, by Messrs. Milne Edwards and Jules Haime, 11 plates.
„ IV. „	1850	The Crag Mollusca, Part II, No. 1, by Mr. S. V. Wood, 12 plates. The Mollusca of the Great Oolite, Part I, Univalves, by Messrs. Morris and Lycett, 15 plates. The Fossil Brachiopoda, Part III, No. 1, Oolitic and Liassic, by Mr. Davidson, 13 plates.
„ V. „	1851	The Reptilia of the Cretaceous Formations, by Prof. Owen, 39 plates. The Fossil Corals, Part II, Oolitic, by Messrs. Milne Edwards and Jules Haime, 19 plates. The Fossil Lepadidæ, by Mr. Charles Darwin, 5 plates.
„ VI. „	1852	The Fossil Corals, Part III, Permian and Mountain-limestone, by Messrs. Milne Edwards and Jules Haime, 16 plates. The Fossil Brachiopoda, Part I, Tertiary, by Mr. Davidson, 2 plates. The Fossil Brachiopoda, Part II, No. 1, Cretaceous, by Mr. Davidson, 5 plates. The Fossil Brachiopoda, Part III, No. 2, Oolitic and Liassic, by Mr. Davidson, 5 plates. The Eocene Mollusca, Part II, Pulmonata, by Mr. F. E. Edwards, 6 plates. The Radiaria of the Crag, London Clay, &c., by Prof. E. Forbes, 4 plates.
„ VII. „	1853	The Fossil Corals, Part IV, Devonian, by Messrs. Milne Edwards and Jules Haime, 10 plates. The Fossil Brachiopoda, Introduction to Vol. I, by Mr. Davidson, 9 plates. The Mollusca of the Chalk, Part I, Cephalopoda, by Mr. D. Sharpe, 10 plates. The Mollusca of the Great Oolite, Part II, Bivalves, by Messrs. Morris and Lycett, 8 plates. The Mollusca of the Crag, Part II, No. 2, Bivalves, by Mr. S. V. Wood, 8 plates. The Reptilia of the Wealden Formations, Part I, Chelonia, by Prof. Owen, 9 plates.

* The Volume for the year 1849 consists of two separate portions, each of which is stitched in a paper cover, on which are printed the dates 1848, 1849, and 1850.

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Vol. VIII.	Issued for the Year *1854	The Fossil Brachiopoda, Part II, No. 2, Cretaceous, with Appendix and Index to Vol. I, by Mr. Davidson, 8 plates. The Reptilia of the Wealden Formations, Part II, Dinosauria, by Prof. Owen, 20 plates. The Mollusca of the Great Oolite, Part III, Bivalves, by Messrs. Morris and Lycett, 7 plates. The Fossil Corals, Part V, Silurian, by Messrs. Milne Edwards and Jules Haime, 16 plates. The Fossil Balanidæ and Verrucidæ, by Mr. Charles Darwin, 2 plates. The Mollusca of the Chalk, Part II, Cephalopoda, by Mr. D. Sharpe, 6 plates. The Eocene Mollusca, Part III, No. 1, Prosobranchiata, by Mr. F. E. Edwards, 8 plates.
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„ XIII.	„ 1859	The Fossil Brachiopoda, Part V, No. 4, Carboniferous, by Mr. Davidson, 20 plates. The Reptilia of the Oolitic Formations, No. 1, Lower Lias, by Prof. Owen, 6 plates. The Reptilia of the Kimmeridge Clay, No. 1, by Prof. Owen, 1 plate. The Eocene Mollusca, Part IV, No. 1, Bivalves, by Mr. S. V. Wood, 13 plates.
„ XIV.	„ 1860	The Fossil Brachiopoda, Part V, No. 5, Carboniferous, by Mr. Davidson, 8 plates. The Reptilia of the Oolitic Formations, No. 2, Lower Lias, by Prof. Owen, 11 plates. The Reptilia of the Kimmeridge Clay, No. 2, by Prof. Owen, 1 plate. The Fossil Estheriæ, by Prof. Rupert Jones, 5 plates. The Fossil Crustacea, Part II, Gault and Greensand, by Prof. Bell, 11 plates.
„ XV.	„ 1861	The Fossil Echinodermata, Oolitic, Vol. II, Part I (Asteroidea), by Dr. Wright, 13 plates. Supplement to the Great Oolite Mollusca, by Dr. Lycett, 15 plates.
„ XVI.	„ 1862	The Fossil Echinodermata, Cretaceous, Vol. I, Part I, by Dr. Wright, 11 plates. The Trilobites of the Silurian, Devonian, &c., Formations, Part I (Devonian and Silurian), by Mr. J. W. Salter, 6 plates. The Fossil Brachiopoda, Part VI, No. 1, Devonian, by Mr. Davidson, 9 plates. The Eocene Mollusca, Part IV, No. 2, Bivalves, by Mr. S. V. Wood, 7 plates. The Reptilia of the Cretaceous and Wealden Formations (Supplements), by Prof. Owen, 10 plates.

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„ XVIII.	„ 1864	The Fossil Echinodermata, Oolitic, Vol. II, Part II (Liassic Ophiuroidea), by Dr. Wright, 6 plates. The Trilobites of the Silurian, Devonian, &c., Formations, Part III, by Mr. J. W. Salter, 11 plates. The Belemnitidæ, Part II, Liassic Belemnites, by Prof. Phillips, 7 plates. The Pleistocene Mammalia, Part I, Introduction, Felis spelæa, by Messrs. W. Boyd Dawkins and W. A. Sanford, 5 plates. Title-pages, &c., to the Monographs on the Reptilia of the London Clay, Cretaceous and Wealden Formations.
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„ XXX.*	„ 1876	The Carboniferous and Permian Foraminifera (the genus Fusulina excepted), by Mr. H. B. Brady, 12 plates. Supplement to the Fossil Brachiopoda, Part II, No. 1 (Jurassic and Triassic), by Mr. Davidson, 8 plates. Supplement to the Reptilia of the Wealden (Poikilopleuron and Chondrosteosaurus), No. VII, by Prof. Owen, 6 plates.
„ XXXI.*	„ 1877	Supplement to the Eocene Mollusca (Bivalves), by Mr. S. V. Wood, 2 plates. The Fossil Trigoniæ, No. IV, by Dr. Lycett, 13 plates. The Eocene Mollusca (Univalves), Part IV, by Mr. S. V. Wood, 1 plate. The Carboniferous Ganoid Fishes, Part I (Palæoniscidæ), by Dr. Traquair, 7 plates. The Fossil Reptilia of the Mesozoic Formations, Part III, by Prof. Owen, 2 plates. The Fossil Elephants (E. antiquus), Part I, by Prof. Leith Adams, 5 plates.
„ XXXII.*	„ 1878	The Fossil Echinodermata, Cretaceous, Vol. I, Part VIII, by Dr. Wright, 8 plates. Index and Title Page to the Fossil Echinodermata, Oolitic, Vol. I (Echinoidea), by Dr. Wright. The Fossil Merostomata, Part V (Neolimulus, &c.), by Dr. H. Woodward, 6 plates. Supplement to the Fossil Brachiopoda, Part II, No. 2 (Jurassic and Triassic), by Mr. Davidson, 13 plates. The Lias Ammonites, Part I, by Dr. Wright, 8 plates. The Sirenoid and Crossopterygian Ganoids, Part I, by Prof. Miall, 6 plates. Supplement to the Reptilia of the Wealden (Goniopholis, Petrosuchus, and Suchosaurus), No. VIII, by Prof. Owen, 6 plates. The Pleistocene Mammalia, Part A (Preliminary Treatise), by Prof. Boyd Dawkins.

* These Volumes are issued in two forms of binding; first, with all the Monographs stitched together and enclosed in one cover; secondly, with each of the Monographs separate, and the whole of the separate parts placed in an envelope.

CATALOGUE OF WORKS—Continued.

Vol. XXXIII* Issued for the Year 1879
- The Eocene Flora, Part I, by Mr. J. S. Gardner and Baron Ettingshausen, 5 plates.
- Second Supplement to the Crag Mollusca (Univalves and Bivalves), by Mr. S. V. Wood, 6 plates.
- The Fossil Trigoniæ, No. V (*Conclusion*), by Dr. Lycett, 1 plate.
- The Lias Ammonites, Part II, by Dr. Wright, 10 plates.
- Supplement to the Reptilia of the Wealden (Goniopholis, Brachydectes, Nannosuchus, Theriosuchus, and Nuthetes), No. IX, by Prof. Owen, 4 plates.
- The Fossil Elephants (E. primigenius), Part II, by Prof. Leith Adams, 10 plates.

„ XXXIV* „ 1880
- The Eocene Flora, Part II, by Mr. J. S. Gardner and Baron Ettingshausen, 6 plates.
- The Fossil Echinodermata, Oolitic, Vol. II, Part III (Asteroidea and Ophiuroidea), by Dr. Wright, 3 plates.
- Supplement to the Fossil Brachiopoda, Part III (Permian and Carboniferous), by Mr. Davidson, 8 plates.
- The Lias Ammonites, Part III, by Dr. Wright, 22 plates.
- The Reptilia of the London Clay, Vol. II, Part I (Chelone) by Prof. Owen, 2 plates.

„ XXXV* „ 1881
- The Fossil Echinodermata, Cretaceous, Vol. I, Part IX, by Dr. Wright, 6 plates.
- Supplement to the Fossil Brachiopoda, Part IV (Devonian and Silurian, from Budleigh-Salterton Pebble Bed), by Mr. Davidson, 5 plates.
- The Fossil Trigoniæ (Supplement No. 1), by Dr. Lycett.
- The Lias Ammonites, Part IV, by Dr. Wright, 10 plates.
- The Reptilia of the Liassic Formations, Part III (*Conclusion*), by Prof. Owen, 13 plates.
- The Fossil Elephants (E. primigenius and E. meridionalis), Part III (*Conclusion*), by Prof. Leith Adams, 13 plates.

„ XXXVI* „ 1882
- The Eocene Flora, Vol. I, Part III (*Conclusion*), by Mr. J. S. Gardner and Baron Ettingshausen, 2 plates.
- Third Supplement to the Crag Mollusca, by the late Mr. S. V. Wood, 1 plate.
- The Fossil Echinodermata, Cretaceous, Vol. I, Part X (*Conclusion*), by Dr. Wright, 5 plates.
- Supplement to the Fossil Brachiopoda, Vol. IV, Part V (*Conclusion*), by Dr. Davidson.
- Supplement to the Fossil Brachiopoda, Vol. V, Part I (Devonian and Silurian), by Dr. Davidson, 7 plates.
- The Lias Ammonites, Part V, by Dr. Wright, 22 plates.

„ XXXVII* „ 1883
- The Eocene Flora, Vol. II, Part I, by Mr. J. S. Gardner, 9 plates.
- The Trilobites of the Silurian, Devonian, &c., Formations, Part V (*Conclusion*), by the late Mr. J. W. Salter.
- The Carboniferous Trilobites, Part I, by Dr. H. Woodward, 6 plates.
- Supplement to the Fossil Brachiopoda, Vol. V, Part II (Silurian), by Dr. Davidson, 10 plates.
- The Fossil Trigoniæ (Supplement No. 2), by the late Dr. Lycett, 4 plates.
- The Lias Ammonites, Part VI, by Dr. Wright, 8 plates.

„ XXXVIII* „ 1884
- The Eocene Flora, Vol. II, Part II, by Mr. J. S. Gardner, 11 plates.
- The Carboniferous Entomostraca, Part I, No. 2 (*Conclusion*), by Prof. T. Rupert Jones, Mr. J. W. Kirkby, and Prof. G. S. Brady, 2 plates.
- The Carboniferous Trilobites, Part II, by Dr. H. Woodward, 4 plates.
- Supplement to the Fossil Brachiopoda, Vol. V, Part III (*Conclusion*), by Dr. Davidson 4 plates.
- The Lias Ammonites, Part VII, by Dr. Wright, 10 plates.

„ XXXIX* „ 1885
- The Eocene Flora, Vol. II, Part III (*Conclusion*), by Mr. J. S. Gardner, 7 plates.
- The Stromatoporoids, Part I, by Prof. Alleyne Nicholson, 11 plates.
- The Fossil Brachiopoda (Bibliography), Vol. VI (*Conclusion*), by the late Dr. Davidson and Mr. W. H. Dalton.
- The Lias Ammonites, Part VIII (*Conclusion*), by the late Dr. Wright, 1 plate.

* These Volumes are issued in two forms of binding; first, with all the Monographs stitched together and enclosed in one cover; secondly, with each of the Monographs separate, and the whole of the separate parts placed in an envelope.

§ II. LIST OF MONOGRAPHS

Completed, in course of Publication, and in Preparation.

1. MONOGRAPHS which have been COMPLETED, and which may be bound as separate Volumes:—

The Eocene Flora, Vol. I (Filices), by Mr. J. S. Gardner and Baron Ettingshausen. (*Complete in the Volumes for the years* 1879, 1880, *and* 1882. *Title-page, Index, and directions for the binding, will be found in the Volume for* 1882.)

The Eocene Flora, Vol. II (Gymnospermæ), by Mr. J. S. Gardner. (*Complete in the Volumes for* 1883, 1884, *and* 1885. *Title-page, Index, and directions for the binding, will be found in the Volume for* 1885.)

The Carboniferous and Permian Foraminifera (the genus Fusulina excepted), by Mr. H. B. Brady. (*Complete in the Volume for the year* 1876.)

The Tertiary, Cretaceous, Oolitic, Devonian, and Silurian Corals, by MM. Milne-Edwards and J. Haime. (*Complete in the Volumes for the years* 1849, 1851, 1852, 1853, *and* 1854. *The Title-page and Index, with corrected explanations of Plates XVII and XVIII, will be found in the Volume for the year* 1854.)

The Polyzoa of the Crag, by Mr. G. Busk. (*Complete with Title-page and Index in the Volume for the year* 1857.)

The Tertiary Echinodermata, by Professor Forbes. (*Complete with Title-page in the Volume for the year* 1852.)

The Fossil Cirripedes, by Mr. C. Darwin. (*Complete in the Volumes for the years* 1851, 1854, *and* 1858. *The Title-page will be found in the Volume for the year* 1854, *and the Index in the Volume for the year* 1858.

The Post-Tertiary Entomostraca, by Mr. G. S. Brady, the Rev. H. W. Crosskey, and Mr. D. Robertson. (*Complete, with Title-page and Index, in the Volume for the year* 1874.)

The Tertiary Entomostraca, by Prof. T. Rupert Jones. (*Complete, with Title-page and Index, in the Volume for the year* 1855.)

The Cretaceous Entomostraca, by Prof. T. Rupert Jones. (*Complete, with Title-page and Index, in the Volume for the year* 1849.)

The Carboniferous Entomostraca, Part I (Cypridinadæ and their allies), by Prof. T. Rupert Jones, Mr. J. W. Kirkby, and Prof. G. S. Brady. (*Complete, with Title-page and Index, in the Volume for the year* 1884.)

The Fossil Estheriæ, by Prof. T. Rupert Jones. (*Complete, with Title-page and Index, in the Volume for the year* 1860.)

The Trilobites of the Cambrian, Silurian, and Devonian Formations, by Mr. J. W. Salter. (*Complete in the Volumes for the years* 1862, 1863, 1864, 1866, *and* 1883. *The Title-page and Index, with directions for the binding, will be found in the Volume for the year* 1883.)

The Fossil Merostomata, by Dr. H. Woodward. (*Complete in the Volumes for the years* 1865, 1868, 1871, 1872, *and* 1878. *The Title-page and Index, with directions for the binding, will be found in the Volume for the year* 1878.)

The Fossil Brachiopoda (Tertiary, Cretaceous, Oolitic, and Liassic), Vol. I, by Mr. T. Davidson. (*Complete in the Volumes for the years* 1850, 1852, 1853, *and* 1854. *The Index will be found in the Volume for the year* 1854, *and corrected Title-page in that for* 1870.)

The Fossil Brachiopoda (Permian and Carboniferous), Vol. II, by Mr. T. Davidson. (*Complete in the Volumes for the years* 1856, 1857, 1858, 1859, *and* 1860. *The Index will be found in the Volume for the year* 1860, *and corrected Title-page in that for* 1870.)

The Fossil Brachiopoda (Devonian and Silurian), Vol. III, by Mr. T. Davidson. (*Complete in the Volumes for the years* 1862, 1863, 1865, 1866, 1868, *and* 1870. *The Title-page and Index will be found in the Volume for the year* 1870.)

The Fossil Brachiopoda, Vol. IV, by Dr. T. Davidson. Supplements: Tertiary, Cretaceous, Jurassic, Triassic, Permian, and Carboniferous. (*Complete in the Volumes for the years* 1873, 1876, 1878, 1880, 1881, *and* 1882. *The Title-page and Index, with directions for the binding will be found in the Volume for the year* 1882.)

The Fossil Brachiopoda, Vol. V, by Dr. T. Davidson. Supplements: Devonian and Silurian. Appendix to Supplements, General Summary, Catalogue and Index of the British Species. (*Complete in the Volumes for the years* 1882, 1883, *and* 1884. *The Title-page, with directions for the binding will be found in the Volume for* 1884.)

The Fossil Brachiopoda, Vol. VI, by Dr. T. Davidson and Mr. W. H. Dalton. Bibliography. (*Complete in the Volume for the year* 1885.)

The Eocene Bivalves, Vol. I, by Mr. S. V. Wood. (*Complete, with Title-page and Index, in the Volumes for the years* 1859, 1862, *and* 1870. *The directions for the binding will be found in the Volume for the year* 1870.)

Supplement to the Eocene Bivalves, by Mr. S. V. Wood. (*Complete, with Title-page and Index, in the Volume for the year* 1877.)

The Eocene Cephalopoda and Univalves, Vol. I, by Mr. F. E. Edwards and Mr. S. V. Wood. (*Complete in the Volumes for the years* 1848, 1852, 1854, 1855, 1858, *and* 1877. *The Title-page, Index, and directions for the binding, will be found in the Volume for the year* 1877.)

The Mollusca of the Crag, Vol. I, Univalves, by Mr. S. V. Wood. (*The Text, Plates, and Index, will be found in the Volume for the year* 1847, *and the Title-page will be found in the Volume for the year* 1855.)

The Mollusca of the Crag, Vol. II, Bivalves, by Mr. S. V. Wood. (*Complete in the Volumes for the years* 1850, 1853, 1855, 1858, *and* 1873. *The Title-page will be found in the Volume for the year* 1873, *and the Index will be found in the Volume for the year* 1855, *and a Note in the Volume for the year* 1858).

The Mollusca of the Crag, Vol. III, Supplement, by Mr. S. V. Wood. (*Complete in the Volumes for the years* 1871 *and* 1873. *The Title-page and Index will be found in the Volume for the year* 1873.)

Second Supplement to the Crag Mollusca, by Mr. S. V. Wood. (*Complete, with Title-page and Index, in the Volume for the year* 1879.)

Third Supplement to the Crag Mollusca, by Mr. S. V. Wood. (*Complete, with Title-page and Index, in the Volume for the year* 1882.)

The Great Oolite Mollusca, by Professor Morris and Dr. Lycett. (*Complete in the Volumes for the years* 1850, 1853, *and* 1854. *The Title-page and Index will be found in the Volume for the year* 1854.)

The Fossil Trigoniæ, by Dr. Lycett. (*Complete in the Volumes for the years* 1872, 1874, 1875, 1877, *and* 1879. *The directions for the binding will be found in the Volume for the year* 1879.)

Supplement to the Fossil Trigoniæ, by Dr. Lycett. (*Complete in the Volumes for the years* 1881 *and* 1883. *The Title-page, Index, with directions for the binding, will be found in the Volume for the year* 1883.)

The Oolitic Echinodermata, Vol. I, Echinoidea, by Dr. Wright. (*Complete in the Volumes for the years* 1855, 1856, 1857, 1858, *and* 1878. *Title-page, Index, and directions for the binding, will be found in the Volume for the year* 1878.)

The Oolitic Echinodermata, Vol. II, Asteroidea, by Dr. Wright. (*Complete in the Volumes for the years* 1861, 1864, *and* 1880. *Title-page, Index, and directions for the binding, will be found in the Volume for the year* 1880).

The Cretaceous Echinodermata, Vol. I, Echinoidea, by Dr. Wright. (*Complete in the Volumes for the years* 1862, 1867, 1869, 1870, 1872, 1873, 1875, 1878, 1881, *and* 1882. *The Title-page and Index, with directions for the binding, will be found in the Volume for the year* 1882.)

The Cretaceous (Upper) Cephalopoda, by Mr. D. Sharpe. (*Complete in the Volumes for the years* 1853, 1854, *and* 1855, *but wants Title-page and Index.*)

The Lias Ammonites, by Dr. Wright. (*Complete in the Volumes for the years* 1878, 1879, 1880, 1881, 1882, 1883, 1884, *and* 1885. *The Title-page and Index, with directions for the binding, will be found in the Volume for the year* 1885.)

The Fossils of the Permian Formation, by Professor King. *Complete, with Title-page and Index, in the Volume for the year* 1849. *Corrected explanations of Plates XXVIII and XXVIII* will be found in the Volume for the year* 1854.)

The Reptilia of the London Clay (and of the Bracklesham and other Tertiary Beds), Vol. I, by Professors Owen and Bell. (*Complete in the Volumes for the years* 1848, 1849, 1856, *and* 1864. *Directions for the binding, Title-page, and Index, will be found in the Volume for the year* 1864.)

The Reptilia of the Cretaceous Formations, by Prof. Owen. (*Complete in the Volumes for the years* 1851, 1857, 1858, 1862, *and* 1864. *Directions for the binding, Title-page, and Index, will be found in the Volume for the year* 1864.)

The Reptilia of the Wealden and Purbeck Formations, by Professor Owen. (*Complete in the Volumes for the years* 1853, 1854, 1855, 1856, 1857, 1858, 1862, *and* 1864. *Directions for the binding, Title-pages, and Index, will be found in the Volume for the year* 1864.)

The Reptilia of the Liassic Formations, by Professor Owen. (*Complete in the Volumes for the years*, 1859, 1860, 1863, 1869, *and* 1881. *Directions for the binding, Title-pages, and Index, will be found in the Volume for the year* 1881.)

The Fossil Mammalia of the Mesozoic Formations, by Professor Owen. (*Complete, with Title-page and Table of Contents, in the Volume for the year* 1870.)

The Fossil Elephants, by Professor Leith Adams. (*Complete in the Volumes for the years* 1877, 1879, *and* 1881. *Directions for the binding, Title-page, and Index will be found in the Volume for the year* 1881.

2. MONOGRAPHS in course of Publication :†—

The Eocene Flora, by Mr. J. S. Gardner.
The Crag Foraminifera, by Messrs. T. Rupert Jones, W. K. Parker, and H. B. Brady.
The Stromatoporoids, by Prof. H. Alleyne Nicholson.
Supplement to the Fossil Corals, by Dr. Duncan.
The Trilobites, by Dr. H. Woodward.
The Belemnites, by Professor Phillips.*
The Sirenoid and Crossopterygian Ganoids, by Professor Miall.
The Fishes of the Carboniferous Formation, by Prof. Traquair.
The Fishes of the Old Red Sandstone, by Messrs. J. Powrie and E. Ray Lankester, and Professor Traquair.
The Reptilia of the Wealden Formation (Supplements), by Professor Owen.
The Reptilia of the Kimmeridge Clay, by Professor Owen.
The Reptilia of the Mesozoic Formations, by Professor Owen.
The Pleistocene Mammalia, by Messrs. Boyd Dawkins and W. A. Sanford.
The Cetacea of the Crag, by Professor Owen.

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3. MONOGRAPHS which are in course of Preparation :— †

The Fossil Cycadeæ, by Mr. W. Carruthers.
The Carboniferous Flora, by Prof. Williamson.
The Rhizopoda of the Chalk, Chalk Marl, Gault, and Upper Greensand, by Messrs. T. Rupert Jones, W. K. Parker, and H. B. Brady.
The Foraminifera of the Lias, by Mr. H. B. Brady.
The Polyzoa of the Chalk Formation, by Mr. G. Busk.
The Carboniferous Entomostraca, Part II (Leperditiadæ), by Messrs. T. Rupert Jones, J. W. Kirkby, and G. S. Brady.
Supplement to the Tertiary and Cretaceous Entomostraca, by Prof. T. Rupert Jones.
The Wealden, Purbeck, and Jurassic Entomostraca, by Messrs. T. R. Jones and G. S. Brady.
The Cretaceous Mollusca (exclusive of the Brachiopoda), by the Rev. Prof. T. Wiltshire.
The Purbeck Mollusca, by Mr. R. Etheridge.
The Jurassic Gasteropoda, by Mr. Hudleston.
The Rhætic Mollusca, by Mr. R. Etheridge.
The Carboniferous Bivalve Mollusca, by Mr. R. Etheridge, junr.
The Inferior Oolite Ammonites, by Mr. S. S. Buckman.
The Silurian Fish Bed, by Dr. Harley.

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* Unfinished through the death of the Author, but will be continued by Mr. R. Etheridge.

† Members having specimens which might assist the authors in preparing their respective Monographs are requested to communicate in the first instance with the Honorary Secretary.

§ III. Dates of the Issue of the Yearly Volumes of the Palæontographical Society.

Volume	I	for	1847	was	issued to	the Members,		March, 1848.
,,	II	,,	1848	,,	,,	,,		July, 1849.
,,	III	,,	1849	,,	,,	,,		August, 1850.
,,	IV	,,	1850	,,	,,	,,		June, 1851.
,,	V	,,	1851	,,	,,	,,		June, 1851.
,,	VI	,,	1852	,,	,,	,,		August, 1852.
,,	VII	,,	1853	,,	,,	,,		December, 1853.
,,	VIII	,,	1854	,,	,,	,,		May, 1855.
,,	IX	,,	1855	,,	,,	,,		February, 1857.
,,	X	,,	1856	,,	,,	,,		April, 1858.
,,	XI	,,	1857	,,	,,	,,		November, 1859.
,,	XII	,,	1858	,,	,,	,,		March, 1861.
,,	XIII	,,	1859	,,	,,	,,		December, 1861.
,,	XIV	,,	1860	,,	,,	,,		May, 1863.
,,	XV	,,	1861	,,	,,	,,		May, 1863.
,,	XVI	,,	1862	,,	,,	,,		August, 1864.
,,	XVII	,,	1863	,,	,,	,,		June, 1865.
,,	XVIII	,,	1864	,,	,,	,,		April, 1866.
,,	XIX	,,	1865	,,	,,	,,		December, 1866.
,,	XX	,,	1866	,,	,,	,,		June, 1867.
,,	XXI	,,	1867	,,	,,	,,		June, 1868.
,,	XXII	,,	1868	,,	,,	,,		February, 1869.
,,	XXIII	,,	1869	,,	,,	,,		January, 1870.
,,	XXIV	,,	1870	,,	,,	,,		January, 1871.
,,	XXV	,,	1871	,,	,,	,,		June, 1872.
,,	XXVI	,,	1872	,,	,,	,,		October, 1872.
,,	XXVII	,,	1873	,,	,,	,,		February, 1874.
,,	XXVIII	,,	1874	,,	,,	,,		July, 1874.
,,	XXIX	,,	1875	,,	,,	,,		December, 1875.
,,	XXX	,,	1876	,,	,,	,,		December, 1876.
,,	XXXI	,,	1877	,,	,,	,,		February, 1877.
,,	XXXII	,,	1878	,,	,,	,,		March, 1878.
,,	XXXIII	,,	1879	,,	,,	,,		May, 1879.
,,	XXXIV	,,	1880	,,	,,	,,		May, 1880.
,,	XXXV	,,	1881	,,	,,	,,		May, 1881.
,,	XXXVI	,,	1882	,,	,,	,,		June, 1882.
,,	XXXVII	,,	1883	,,	,,	,,		October, 1883.
,,	XXXVIII	,,	1884	,,	,,	,,		December, 1884.
,,	XXXIX	,,	1885	,,	,,	,,		January, 1886.

§ IV. SUMMARY OF THE MONOGRAPHS ISSUED TO THE MEMBERS (*up to* JANUARY, 1886): *showing in the* FIRST *column whether each Monograph hitherto published be* complete, *or in the* course of completion; *in the* SECOND *column, the yearly volumes which contain each particular Monograph (as a guide to binding the same); and in the* FOURTH *and following columns, the number of pages, plates, figures, and species described in the different Monographs.*

I. SUBJECT OF MONOGRAPH.	II. Dates of the Years *for which* the volume containing the Monograph was issued.	III *m*. Dates of the Years *in which* the Monograph was published.	IV. No. of Pages of Letterpress in each Monograph.	V. No. of Plates in each Monograph.	VI. No. of Lithographed Figures and of Woodcuts.	VII. No. of Species described in the Text.
The Flora of the Eocene Formations, by Mr. J. S. Gardner and Baron Ettingshausen. Vol. I, COMPLETE	1879, 1880, 1882	1879, 1880, 1882	87	13	151	23
" " by Mr. J. S. Gardner. Vol. II, COMPLETE	1883, 1884, 1885	1883, 1884, 1886	159	27	400	31
The Flora of the Carboniferous Strata, by Mr. E. W. Binney, *in course of completion*	1867, 1870, 1871, 1875	1868, 1871, 1872, 1875	147	24	141	16
The Crag Foraminifera, by Messrs. T Rupert Jones, W. K. Parker, and H. B. Brady, *in course of completion*	1865	1866	78	4	211	43
The Carboniferous and Permian Foraminifera (genus Fusilina excepted), by Mr. H. B. Brady, COMPLETE	1876	1876	166	12	266	62
The Stromatoporoids, by Prof. Alleyne Nicholson, *in course of completion*	1885	1886	133	11	187	—
Tertiary, Cretaceous, Oolitic, Devonian, and Silurian Corals, by MM. Milne-Edwards and J. Haime, COMPLETE (*k*)	1849, 1851, 1852, 1853, 1854	1850, 1851, 1852, 1853, 1855	406	72	800	319*g*
Supplement to the Fossil Corals, by Prof. Duncan, *in course of completion*	1865, 1866, 1867, 1868, 1869, 1872	1866, 1867, 1868, 1869, 1870, 1872	232	49	797	149
The Polyzoa of the Crag, by Mr. G. Busk, COMPLETE	1857	1859	145	22	641	122
The Tertiary Echinodermata, by Prof. Forbes, COMPLETE	1852	1852	39	4	144	44
The Oolitic Echinodermata, by Dr. Wright. Vol. I, COMPLETE (*l*)	1855, 1856, 1857, 1858, 1878	1857, 1858, 1859, 1861, 1878	491	43	724	120*h*
" " Vol. II, COMPLETE	1861, 1864, 1880	1863, 1866, 1880	207	22	232	35
The Cretaceous Echinodermata, by Dr. Wright. Vol. I, COMPLETE	1862, 1867, 1869, 1870, 1872, 1873, 1875, 1878, 1881, 1882	1864, 1868, 1870, 1871, 1872, 1874, 1875, 1878, 1881, 1882	390	87	1119	113
The Fossil Cirripedes, by Mr. C. Darwin, COMPLETE	1851, 1854, 1858*a*	1851, 1855, 1861	137	7	320	54
The Fossil Merostomata, by Dr. H. Woodward, COMPLETE	1865, 1868, 1871, 1872, 1878	1866, 1869, 1872, 1872, 1878	265	36	365	51
The Post-Tertiary Entomostraca, by Mr. G. S. Brady, Rev. H. W. Crosskey, and Mr. D. Robertson, COMPLETE	1874	1874	237	16	515	134
The Tertiary Entomostraca, by Prof. Rupert Jones, COMPLETE	1855	1857	74	6	233	56
The Cretaceous Entomostraca, by Prof. Rupert Jones, COMPLETE	1849	1850	41	7	176	27
The Carboniferous Entomostraca, by Prof. Rupert Jones and Messrs. J. W. Kirkby and Prof. G. S. Brady. Part I, COMPLETE	1874, 1884	1874, 1884	95	7	374	81
The Fossil Estheriæ, by Prof. Rupert Jones, COMPLETE	1860	1863	139	5	158	19*i*
		CARRIED FORWARD...	3668	474	7954	1499

SUMMARY OF THE MONOGRAPHS ISSUED TO THE MEMBERS (*up to* JANUARY, 1886)—*continued.*

I. SUBJECT OF MONOGRAPH.	II. Dates of the Years *for which* the volume containing the Monograph was issued.	III *m.* Dates of the Years *in which* the Monograph was published.	IV. No. of Pages of Letterpress in each Monograph.	V. No. of Plates in each Monograph.	VI. No. of Lithographed Figures and of Woodcuts.	VII. No. of Species described in the Text.
		BROUGHT FORWARD...	3668	474	7954	1499
The Trilobites of the Cambrian, Silurian, and Devonian Formations, by Mr. J. W. Salter, COMPLETE	1862, 1863, 1864, 1866, 1883	1864, 1865, 1866, 1867, 1883	224	31	703	114
The Carboniferous Trilobites, by Dr. H. Woodward, COMPLETE	1883, 1884	1883, 1884	86	10	148	31
The Malacostracous Crustacea (comprising those of the London Clay, Gault, and Greensands), by Prof. T. Bell, *in course of completion*	1856, 1860	1858, 1863	88	22	215	50
The Fossil Brachiopoda, Vol. I. The Tertiary, Cretaceous, Oolitic, and Liassic Brachiopoda, by Mr. T. Davidson, COMPLETE	1850, 1852, 1853, 1854	1851, 1852, 1853, 1855	409	42	1855	160
„ „ Vol. II. The Permian and Carboniferous Brachiopoda, COMPLETE	1856*d*, 1857, 1858, 1859, 1860	1858, 1859, 1861, 1861, 1863	331	59	1909	157
„ „ Vol. III. The Devonian and Silurian Brachiopoda, COMPLETE	1862, 1863, 1865, 1866, 1868, 1870	1864, 1865, 1866, 1867, 1869, 1871	528	70	2766	321
„ „ Vol. IV. Supplements, Tertiary to Carboniferous, COMPLETE	1873, 1876, 1878, 1880, 1881, 1882	1874, 1876, 1878, 1880, 1881, 1882	383	42	1664	215
„ „ Vol. V. Supplements, Devonian and Silurian, COMPLETE	1882, 1883, 1884	1882, 1883, 1884	476	21	1135	116
„ „ Vol. VI. Bibliography, COMPLETE	1885	1886	163	—	—	—
The Fossil Trigoniæ, by Dr. Lycett, COMPLETE	1872, 1874, 1875, 1877, 1879	1872, 1874, 1875, 1877, 1879	246	41	446	115
Supplement to the Fossil Trigoniæ, by Dr. Lycett, COMPLETE	1881, 1883	1881, 1883	19	4	53	9*h*
The Mollusca of the Crag, by Mr. S. V. Wood:—						
Vol. I. (Univalves), COMPLETE	1847, 1855*b*	1848, 1857	216	21	581	244
Vol. II. (Bivalves), COMPLETE	1850, 1853, 1855, 1858*c*	1851, 1853, 1857, 1861	344	31	691	253
Supplements to the Crag Mollusca, No. I and II, by Mr. S. V. Wood, COMPLETE	1871, 1873, 1879	1872, 1874, 1879	322	18	517	232
„ „ No. III „ COMPLETE	1882	1882	24	1	29	13
The Eocene Mollusca, Cephalopoda and Univalves, by Mr. F. E. Edwards, continued by Mr. S. V. Wood. Vol. I, COMPLETE	1848, 1852, 1854, 1855, 1858, 1877	1849, 1852, 1855, 1857, 1861, 1877	361	34	625	275
The Eocene Mollusca, Bivalves, by Mr. S. V. Wood. Vol. I, COMPLETE	1859, 1862, 1870	1861, 1864, 1871	182	25	531	194
Supplement to the Eocene Mollusca, by Mr. S. V. Wood (Bivalves). Vol. I, COMPLETE	1877	1877	24	2	66	30
The Great Oolite Mollusca, by Prof. Morris and Dr. Lycett, COMPLETE	1850, 1853, 1854	1850, 1853, 1855	282	30	846	419
„ „ „ Supplement by Dr. Lycett, COMPLETE	1861	1863	129	15	337	194
The Liassic Ammonites, by Dr. Wright, COMPLETE	1878, 1879, 1880, 1881, 1882, 1883, 1884, 1885	1878, 1879, 1880, 1881, 1882, 1883, 1884, 1886	503	91	726	107
The Belemnites, by Prof. Phillips, *in course of completion*	1863, 1864, 1866, 1868, 1869	1865, 1866, 1867, 1869, 1870	128	36	622	69
		CARRIED FORWARD...	9136	1120	24,419	4817

Summary of the Monographs issued to the Members (*up to* JANUARY, 1886)—*continued.*

I. SUBJECT OF MONOGRAPH.	II. Dates of the Years *for which* the volume containing the Monograph was issued.	III *m*. Dates of the Years *in which* the Monograph was published.	IV. No. of Pages of Letterpress in each Monograph.	V. No. of Plates in each Monograph.	VI. No. of Lithographed Figures and of Woodcuts.	VII. No. of Species described in the Text.
		BROUGHT FORWARD...	9136	1120	24,419	4817
The Upper Cretaceous Cephalopoda, by Mr. D. Sharpe, COMPLETE	1853, 1854, 1855	1853, 1855, 1857	67	27	319	79
The Fossils of the Permian Formation, by Prof. King, COMPLETE	1849, 1854*e*	1850, 1855	287	29	511	138
The Sirenoid Ganoids, by Prof. Miall, *in course of completion*	1878	1878	32	6	61	6
The Fishes of the Carboniferous Formation, by Dr. Traquair, *in course of completion*	1877	1877	60	7	58	5
The Fishes of the Old Red Sandstone, by Messrs. J. Powrie and E. Ray Lankester, *in course of completion*	1867, 1869	1868, 1870	62	14	195	21
The Reptilia of the London Clay [and of the Bracklesham and other Tertiary Beds], by Profs. Owen and Bell, Vol. I, COMPLETE ‡	1848, 1849, 1856*f*	1849, 1850, 1859	150	58	304	39
,, ,, Vol. II, Part I, by Prof. Owen, *in course of completion*	1880	1880	4	2	4	1
The Reptilia of the Cretaceous Formations, by Prof. Owen, COMPLETE‡	1851, 1857, 1858, 1862	1851, 1859, 1861, 1864	184	59	519	26
The Reptilia of the Wealden and Purbeck Formations, by Prof. Owen, COMPLETE ‡	1853, 1854, 1855, 1856, 1857, 1858, 1862	1853, 1855, 1857, 1858, 1859, 1861, 1864	155	62	251	17
The Reptilia of the Wealden Formations (Supplements) *in course of completion*	1871, 1873, 1876, 1878, 1879	1872, 1874, 1876, 1878, 1879	81	21	175	15
The Reptilia of the Kimmeridge Clay Formation, by Prof. Owen, *in course of completion*	1859, 1860, 1868	1861, 1863, 1869	16	6	23	3
The Reptilia of the Liassic Formations, by Prof. Owen, COMPLETE	1859,‖ 1860,‖ 1863, 1869, 1881*n*	1861, 1863, 1865, 1870, 1881	174	50	276	20
The Reptilia of the Mesozoic Formations, by Prof. Owen, *in course of completion*	1873, 1875, 1877	1874, 1875, 1877	97	24	165	17
The Crag Cetacea, by Prof. Owen, *in course of completion*	1869	1870	40	5	43	7
The Fossil Elephants, by Prof. Leith Adams, COMPLETE	1877, 1879, 1881*n*	1877, 1879, 1881	265	28	216	3
The Pleistocene Mammalia, by Messrs. W. Boyd Dawkins and W. A. Sanford, *in course of completion*	1864, 1867, 1868, 1871, 1878	1866, 1868, 1869, 1872, 1878	304	32	253	7
The Mammalia of the Mesozoic Formations, by Prof. Owen, COMPLETE	1870	1871	115	4	247	30
		TOTAL	11,229	1554	28,039	5251

a Index. *b* Title-page to Univalves. *c* Note to Crag Mollusca. *d* Contains the Permian. *e* Two corrections of Plates. *f* Supplement.
g Many of the species are described, but not figured. *h* British species only reckoned. *i* British species only reckoned. *k* A Supplement is now in course of publication.
l Index will be found in 1878 vol. *m* Useful for establishing the dates of new species. *n* Contains title-pages and directions for binding.
‡ Title-pages and Index will be found in the 1864 Volume, or may be had separately. ‖ Marked on outside label 'Reptilia of Oolitic Formations.'

§ V. Stratigraphical Table *exhibiting the* British Fossils *already figured and described in the* Annual Volumes (1847—1885) *of the* Palæontographical Society.

	PLANTS.	PROTOZOA.		RADIATA.		ARTICULATA.					
		Sponges.	Foraminifera.	Stromatoporoids and Corals.	Echinodermata.	Cirripedes.	Cypridæ, Cytherinæ, &c.	Estheriæ.	Merostomata.	Trilobites.	Malacostracous Crustacea.
Pleistocene	...	...	...	...	......	......	1874				
Crag	...	...	1865	1849	1852	1851, 1854					
Eocene	1879, 1880, 1882, 1883, 1884, 1885	...	...	1849, 1865	1852	1851, 1854	1855	...	......	......	1856
Cretaceous.........	...	...	...	1849, 1868, 1869	1862, 1867, 1869, 1870, 1872, 1873, 1875, 1878, 1881, 1882	1851, 1854	1849	...	......	......	1860
Wealden	...	...	...	...	......	......	...	1860			
Oolitic	...	...	...	1851, 1872	1855, 1856, 1857, 1858, 1861, 1878, 1880	1851	...	1860			
Liassic	...	...	...	1851, 1866, 1867	1855, 1856, 1858, 1861, 1864						
Triassic	...	...	...	...	1880	......	...	1860			
Permian	1849	1849	1849, 1876	1849, 1852	1849	......	1849	1860			
Carboniferous...	1867, 1870, 1871, 1875	...	1876	1852	......	......	1874, 1884	1860	1872, 1878	1883, 1884	
Devonian	...	...	...	1853, 1885	......	......	...	1860	1865, 1868, 1872, 1878	1862	
Silurian............	...	...	...	1854, 1885	......	......	...	...	1868, 1871, 1872, 1878	1862, 1863, 1864, 1866	
Cambrian	...	...	...	...	......	......	...	...	......	1864	

Note.—The numbers in the above List refer to the Volumes issued for those Dates.

STRATIGRAPHICAL TABLE *exhibiting the* BRITISH FOSSILS *already figured and described in the* ANNUAL VOLUMES (1847—1885) *of the* PALÆONTOGRAPHICAL SOCIETY (*continued*).

	MOLLUSCA.				VERTEBRATA.		
	Polyzoa.	Brachiopoda.	Monomyaria, Dimyaria, and Gasteropoda.	Cephalopoda.	Fishes.	Reptiles.	Mammalia.
Pleistocene	...	1873	......	...	...	......	1864 1867 1868 1871 1877 1878 1879 1881
Crag	1857	1852 1873 1879	1847, 1850, 1853, 1855, 1871, 1873, 1879, 1882	...	...	......	1869 1881
Eocene	...	1852 1873	1852, 1854, 1855, 1858, 1859, 1862, 1870, 1877	1848	...	1848, 1849, 1856, 1880	
Cretaceous.........	...	1852, 1854, 1873, 1884	1872 1875 1877 1879	1853 1854 1855	...	1851, 1857, 1858, 1862	
Wealden	...	... ..	......	...	...	1853, 1854, 1855, 1856, 1857, 1862, 1871, 1873, 1875, 1876, 1878, 1879	
Oolitic	...	1850, 1852, 1876, 1878, 1884	1850, 1853, 1854, 1872, 1874, 1875, 1877, 1879, 1883	1850 1861 1868 1869	...	(Purbeck) 1853, 1858 (Kim. Clay), 1859, 1860, 1868, 1873, 1875, 1877 (Great Oolite) 1875	1870
Liassic	...	1850, 1852, 1876, 1878, 1884	1874, 1877, 1879, 1883	1863, 1864, 1866, 1868, 1878, 1879, 1880, 1881, 1882, 1883, 1884, 1885,	...	1859, 1860, 1863, 1869, 1873, 1881	
Triassic............	...	1876, 1878	1879	......	1878	......	1870
Permian	1849	1849, 1856, 1880	1849	1849	1849	1849	
Carboniferous ...	...	1856, 1857, 1858, 1859, 1860, 1880, 1884	......	......	1877		
Devonian	...	1862, 1863, 1881, 1882, 1884	......	......	1867 1869		
Silurian............	...	1865, 1866, 1868, 1870, 1881, 1882, 1883					
Cambrian							

NOTE.—The numbers in the above List refer to the Volumes issued for those Dates.

THE

PALÆONTOGRAPHICAL SOCIETY.

INSTITUTED MDCCCXLVII.

LONDON:

MDCCCLXXXIII—MDCCCLXXXVI.

BRITISH EOCENE FLORA.

DIRECTIONS TO THE BINDER.

The Monograph of the British Eocene Flora (Volume II) will be found in the publications of the Palæontographical Society for the years 1883, 1884, and 1885.

Cancel the Title-pages of Parts I and II in the volumes of the Palæontographical Society for the years 1883 and 1884 ; *cancel* also pages 91 and 92 in the volume of the Palæontographical Society for the year 1884 ; *substitute* the Title-page now provided, and follow the order of binding given in the accompanying table of pages, plates, and dates.

ORDER OF BINDING AND DATES OF PUBLICATION OF VOLUME II.

	PAGES	PLATES	ISSUED IN VOL. FOR YEAR	PUBLISHED
Part III	Title-page, Contents		1885	January, 1886
Part I	1—60	I—IX	1883	October, 1883
Part II	61—90	X—XX	1884	December, 1884
Part III	91—159	XXI—XXVII	1885	January, 1886

A MONOGRAPH

OF THE

BRITISH EOCENE FLORA.

BY

JOHN STARKIE GARDNER, F.L.S., G.S., M.G.S. France, &c.

VOL. II.

GYMNOSPERMÆ.

LONDON:
PRINTED FOR THE PALÆONTOGRAPHICAL SOCIETY.
1883—1886.

PRINTED BY
J. E. ADLARD, BARTHOLOMEW CLOSE.

indication of the position of the scales on the axis, and their formation seems somewhat different. I do not therefore at present feel that the material would justify the transfer of the Bovey specimens to another genus, especially as their reference to *Sequoia* has been very widely accepted in text-books, and the supposed presence of a representative of the giant trees of California made the basis of much speculation and inference. I think it almost certain, however, that the species may be found not to be a true *Sequoia*; and the danger is very apparent of giving the reins to the imagination and picturing the slopes round the ancient Bovey water as clothed with woods composed " mainly of a huge coniferous tree (*Sequoia Couttsiæ*), whose figure resembled in all probability its highly admired cousin, the *Sequoia* (*Wellingtonia*) *gigantea*, Lindl., of California."[1] If the supposed *Wellingtonia* should prove to be but a marsh-loving plant, as the supposed tree-ferns of "imposing grandeur" have proved to be but humble Osmundas, how completely at variance must the actual appearance of the vegetation have been to that so graphically described in Heer and Pengelly's work.

The Hordwell specimens are indistinguishable from *Athrotaxis cupressoides* of Tasmania, " a small erect tree, from twenty to thirty feet high, much branched, and with numerous branchlets, which are slender, spreading or pendulous, and cylindrical."[2] "It is found at Lake St.-Claire and along Pine River, in Tasmania, and is tolerably hardy." The *Athrotaxides* form a small genus, allied to *Sequoia*, now entirely confined to Tasmania. The fact that the species are little known and are still rare in herbaria has no doubt prevented hitherto the reference of any fossils to the genus. The occurrence of two undoubted and almost unaltered species in our Eocene is not a little singular, and of great significance.

The specimens obtained from the Bembridge Marls, Gurnet Bay, occur above the "Insect Bed," and unlike those previously described are *in intaglio*. They prove, though relatively rare, that the species maintained its ground between the Hordwell and Hempstead horizons; from both of these it had previously been obtained. They are figured Plate XXII, fig. 10; Plate XXVII, figs. 4, 4, *a*.

SEQUOIA SHRUBSOLEI, sp. nov.

London Clay; Sheppey.

The cone is ovate, 37 millimètres in length; 20 millimètres in its widest diameter, and about one third less when measured from back to front or at right angles to the plane shown in the figure. Before compression, therefore, it must have been of a cylindrical form, shaped like a cocoon, and about twice as wide as high, and rather obtuse at both ends. It is composed of about 40 scales, lozenge-shaped, or imperfectly hexagonal, measuring 10 millimètres across and 8 in height, becoming smaller towards

[1] " Flora of Bovey," ' Phil. Trans.,' 1862.

[2] Gordon's ' Pinetum,' p. 47, 1880.

the apex of the cone, and very slightly diminishing towards its base: they are sunken in the middle, and have been considerably abraded. The cone was embedded before the scales had gaped, and still adheres to a stout footstalk 7 millimètres across.

FIG. 35.—*Sequoia Shrubsolei.* London Clay; Isle of Sheppey.

These characters agree well with *Sequoia,* and in all probability the fossil belonged to a species of the *S. gigantea* type (Fig. 12, p. 33). The fact that the scales are tightly closed, are preserved in pyrites instead of lignite, that they had undergone compression, and that the petiole had a relative stoutness, all favour the assumption that the cone had not reached maturity when detached from the tree. There is no other existing genus to which it could possibly be referred except *Pinus.*

It reached me among a parcel of fruits sent from Sheerness by Mr. W. H. Shrubsole, F.G.S., and is, so far as I know, a unique specimen.

TAXODIUM EUROPÆUM,[1] *Brongt.* Plate XXIV.

Reading Beds; Reading.

The species was fully described at page 30 of this memoir. The beautiful specimen figured (Plate XXIV) and another from below the Mottled Clay at Reading, were obtained this summer, and show that a species, once claimed to be typical of the Miocene, flourished in our area long before ever the Palms and other tropical plants of the London Clay of Sheppey, and of the Lower Bagshot of Alum Bay, had become introduced. The stratigraphical evidence as to their age is fortunately so good, the London Clay actually capping the Mottled Clay in another part of the quarry, that it is beyond cavil. The whole of the assemblage of plants, which are of remarkably temperate aspect, must, when they become better known, force every one to admit that preconceived ideas as to what are Eocene and what Miocene plants must be banished, and the entire evidence sifted afresh.

The imbricated and distichous foliage are present on the same branches in both the figured and an unfigured specimen. Fragments of Pine-needles, which afford no sufficient material for specific description, accompany it, together with a flower[2] or fruit and dicotyledonous leaves. The matrix is a clay of a pale French-grey colour, very friable, but with perfectly distinct impressions of the vegetable remains, and separated from the overlying Mottled Clay by a few feet of clean white sand. The discovery carries back

[1] See *ante*, p. 30.

[2] Saporta is inclined to believe that this may be a detached cone of a Callitris or Widdringtonia, such as are met with commonly in the gypsum of Aix. He also remarks upon the resemblance of the Glyptostrobus to an extinct Eocene Sequoia described by himself.

the first appearance of the species a very long way, for none older than the Middle Bagshot were previously known. *Anemia subcretacea*, a Fern, is also associated with it both at Bournemouth and Reading.

Specimens have been found in the Woolwich Beds of the Park-Hill cutting at Croydon, resembling *Athrotaxis Couttsiæ*, though even more slender, but it is probable that they may have belonged to the same species as this from Reading.

Doliostrobus Sternbergii, *Goeppert*, sp. Plates XXII and XXIII.

Araucarites Sternbergii, *Goeppert* (pars). Ettingshausen, Die Tertiäre Flora von Häring in Tirol, p. 36, pls. vii and viii, 1853.
Sequoia — *Heer*. Urw. d. Schweiz, p. 310, 1864, and all later works.
Doliostrobus — *Marion*, Comptes rendus de l'Acad. des Sciences, 1884.

The Bembridge Marls; Gurnet Bay, Isle of Wight.

The leaves are spirally arranged, awl-shape or falcate, rigid, sharply pointed, keeled dorsally, grooved on their inner face; they are very short near the bases of the branchlets and reach to an extreme length of 9 millimètres, or 13 mm. if the decurrent base be included. Stouter branchlets (figs. 1 and 4, Plate XXII) are clothed with denser and more scale-like leaves. The branchlets seem relatively long and slender, as if the habit of the tree had been lax; and they fork irregularly, but not copiously, at a mean angle of 45°; the terminal shoots being long and simple. Part of a branch (fig. 12) is marked with the inlaid scars common to many of the Coniferæ, resembling scale-armour, the diameter of the scales being about 3 mm., their edges raised, and centres depressed, showing that the branches must have been clothed with broad-based spinous leaves as in the existing needle-leaved *Araucariæ*. There are unfortunately no traces of the fruiting organs among the numerous specimens I have examined, with the single exception of the detached scale occurring on the specimen, fig. 5, Plate XXII.[1] It is slightly curled and with thin margins, widest near the apex, which is acuminate and thickened, tapering to the base, 7 mm. in width and about the same in height.

There is thus little beyond the foliage to help us to the nature of the plant, and it is hardly necessary to state that no botanist would undertake the determination of any living Conifer, presented to him for the first time, on such material. The palæontologist has, however, to accept such specimens as are procurable, and to

[1] Mr. A'Court Smith, who collected them, writes that there were a number of "round discs," which he chipped away in reducing the stones. He adds that their absence may also probably be due to his having failed to look out for them or to recognise their nature.

supply by inference that of which he lacks direct proof. That many have abused this privilege, and come to heedless and unjustifiable determinations of fossil plants, is but too well known; but when their determination can be based on consistent reasoning they should not be set aside too summarily, but accepted with due regard for what they may be worth.

Foliage of this character is not distinctive of any particular genus, or even tribe of Coniferæ, but is met with in *Sequoia*, *Cryptomeria*, *Athrotaxis*, *Araucaria*, and *Dacrydium*, as well as in many extinct genera. In the present instance, it appears to have fallen into river-water that flowed sluggishly, for it abounded in molluscous, and sometimes in insect life, while seeds, twigs, and other objects with differing powers of flotation were embedded together in an oozy sediment. If cones had been adhering to the branches when they fell, they must, under such conditions, have been embedded together. With regard to *Cryptomeria*, Mr. Cossart writes, in reply to my inquiry, that the mature cones are most difficult to detach, and that they remain united to the branchlets that have been shed until these become half rotten. We have also seen them attached in the fossil state (see Plate XXI). I am not aware whether the cones of the Mammoth Tree are shed separately from the foliage, but they have usually been found associated together in the fossil state. *Sequoia* cones, moreover, could not have escaped a collector's notice had they been present in numbers at all proportioned to the foliage. We have seen cones and foliage associated in two species of fossil *Athrotaxis*, and their complete absence in this case almost compels us therefore to exclude all these Taxodieæ from our comparisons. It cannot be assimilated to any existing species of Juniper or Dacrydium, and in no case in fact does the foliage of any berry-producing Conifer resemble it at all closely. We must therefore look for it among those Coniferæ the axes of whose cones remain permanently fixed on the trees, unless accidentally removed, while their deciduous scales and seeds are scattered afar by the winds.

Dr. Marion, of Marseilles, has met with the fac-simile of our fossil in great abundance in the Oligocene of the Tertiary basin of Alais, Gard, between the horizon of *Paloplotherium minus* and the Sandstones with *Anthracotherium*, or as nearly as possible on the same horizon as the Bembridge Marls at Gurnet Bay. The branches of this Conifer are scattered in profusion over the flags of a certain bed at Ceylas, almost to the exclusion of other plant impressions. They are often of large size, and seem to have been shed and not broken from the tree. Dr. Marion describes, in addition to the ordinary falcate leaves, branches clothed with longer and straighter needles scarcely curved at their extremities, the two varieties being always associated together.[1] Scattered over some of

[1] "À côté du type ordinaire, on observe des branches dont les appendices prennent, en s'allongeant, la forme en aiguille droite ou à peine recourbée à l'extrémité. Ces deux sortes de rameaux sont tonjours associées; je ne pense pas qu'elles indiquent deux espèces distinctes," l. c., p. 2. A more detailed description of *Doliostrobus* by the same author is in the press. I met with a fragment some years since in the Bembridge Marls bearing somewhat similar needles to those described, and referred to it at p. 59, pl. xiii, fig. 7.

the slabs are numbers of detached scales very variable in form, more elongate, mucronate, and striate, but in other respects resembling ours (fig. 5, Plate XXII). The cones to which they belonged were terminal and attained a length of 4 centimètres. The scales and seeds were shed when ripe, and the axis remained firmly attached to the branch. Dr. Marion has obtained specimens, not only of the axis wholly and partially stripped, but of entire cones accidentally detached before fully mature. The seeds were free and winged on one side only, precisely as in Agathis.

FIG. 36.—Slab comprising the bare axis of a cone, some loose scales, and a seed; Ceylas. From a drawing communicated by Dr. Marion.

In this, as in other instances, our own insufficient data have been supplemented by more ample material from other countries. The foliage from the Isle of Wight, identified by careful comparison, not of drawings only but of actual specimens, with foliage from the same horizon in France, has enabled us to determine the true nature of the plant to which it belonged with almost as much precision as if the fruiting organs had also been found at Gurnet Bay; thus the inference we should probably have come to independently, is verified. The French deposits were lacustrine, and everything that fell on the water in due time sank and became mingled together. In the moving water, which deposited the Bembridge and Hempstead muds, we can only suppose that the light and dry scales and seeds, though shed in profusion, were carried far away by the stream, however sluggish, or stranded on adjacent shores by the breeze.

Though we may feel confidence in the identification of this species with the French form, it is not so certain when comparison is made farther afield. A similar, but far more robust form of foliage has been noticed from the much older beds of Bournemouth, and identified with *Araucaria Cunninghami*, though a distinctive name was retained for the fossil (Plate XII). We have also foliage closely resembling it in *Cryptomeria Sternbergii* (Plate XXI), though the former can be distinguished by its larger and less tufted appearance and wider angles of divergence, and in *Athrotaxis subulata* (Plate XI).

It is impossible, however, to attempt to apportion the published drawings and descriptions of similar foliage from other Tertiary deposits of Europe, often of unknown age, to these four species. The cone from Häring, originally figured by Sternberg and

by Goeppert, already referred to (p. 57), is oval and elongated and clothed with bracts, and appears more like that of *Araucaria* than of *Doliostrobus*. A cone from the same locality sent to me by Ettingshausen (Fig. 37) is smaller and round, and agrees exactly with those described by Marion. Both kinds of foliage, as well as detached scales, are also met with, and there can be no reasonable doubt that the same or a closely similar species of *Doliostrobus* occurs at Häring at least. Marion informs me that Heer had accepted his conclusions, although he still maintained that the second cone from Chiavon[1] belonged to a different genus. I do not see at present any reason for modifying my former views regarding it, and leave it and the associated foliage, together with that from Bournemouth, in *Araucaria*. *Doliostrobus* is undoubtedly a very ancient form, and it may be a descendant of *Pachyphyllum* as surmised by Marion, as, indeed, may also be our Sheppey *Athrotaxis*. The genus is also present in the Upper Cretaceous of Patoot, for scales described as *Dammara* are associated with foliage called *Sequoia*.[2] There need be no difficulty in admitting that *Araucaria* grew contemporaneously with it in Europe, as the former has actually been traced in France as high as the Upper Senonian.

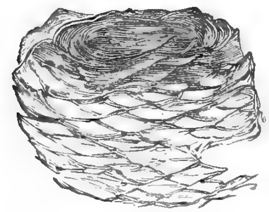

Fig. 37.—Cone of *Doliostrobus Sternbergii*, from Häring.

Had the fossil been a living plant, it would probably have been placed in *Agathis* notwithstanding that no similar foliage had previously been met with in that genus; for we find in *Araucaria* that a species is not excluded because the scales are persistent. As at present defined, however, *Agathis* is characterised by the persistence of its scales, and a fossil species with deciduous scales cannot therefore be included in it.

All the specimens have been collected by Mr. E. A'Court Smith, and they number at least thirty or forty. He writes that they are found from the very base of the Bembridge Marls upwards, almost wherever vegetable remains occur; and specimens I have seen are in matrices of all shades of colour, red, yellow, grey, white, and fawn. The finest occur in septarian concretions, of an ochreous brown externally and pale fawn colour inside, with an extremely fine grain. The septaria are irregularly scattered, from half a foot to two feet in length, with a somewhat conchoidal and very uncertain fracture. The branchlets occur on the exterior as well as in the interior, being best preserved in the latter case. The leaves and stems are in a shrunken carbonised state in hollow cavities, which seem to be exact moulds of the Conifer as it was when first embedded. The stone is often stained for a short distance, a ferruginous brown margining the contour of the mould. The branches are generally slightly compressed horizontally, but sometimes lie vertically squeezed along the cracks. The origin of these blocks which seem to have segregated round the vegetable remains presents an interesting problem. It is clear that they became cracked or fissured while still soft, the lines of fissure following in two cases the thickest stems, and that the compression

[1] See p. 57.

[2] 'Flora Arctica,' vol. vii, pl. liii.

was greater laterally than vertically. The remains of the Conifer are occasionally associated with reedy plants, but are more often found almost unmixed with other vegetation.

Podocarpus Campbelli, sp. nov. Plate XXVI.

Basaltic Formation; Ardtun Head, Isle of Mull.

The leaves are linear-lanceolate, straight or slightly curved, tapering gradually from near the base to a sharp apex, constricted at the base, slightly twisted at the point of attachment, and decurrent as in all distichous Conifers. Their extreme length does not exceed 7 centimètres and breadth 7 millimètres. The mid-rib is distinct, but not salient. There is no trace of secondary ribs, but the whole surface has a finely striate and silky texture. The leaf was leathery and the epidermis dense, with the peculiar loosely-fitting appearance seen in some recent Podocarps, such as *P. neriifolia.* Its thickness and the peculiarity of its structure is revealed where one, and even two distinct layers of tissue have peeled off without injury to the contour of the leaf. The margins, as in all dense and leathery leaves, are particularly well-defined, and were, perhaps, very slightly reflected or curled, as in some living species. The very thin outer epidermis is of a pale vandyke-brown, but when this is stript, the substance of the leaf exposed underneath is warm drab in colour. The specimen, Plate XXVI, fig. 3, shows a longitudinal stripe of richer brown on each side of the mid-rib. The leaves were generally shed singly, and are found scattered on the surfaces of the stone as in fig. 1, where the rupture is seen to have been transverse, leaving the detached leaf without petiole, and with a constricted and truncated base. More rarely they fell still attached to the branchlets, as in figs. 2 and 3, when they are seen to have been sparsely and roughly arranged or pressed into two rows, though somewhat irrregularly, being neither opposite nor alternate, and generally set at almost right-angles to the stem. It seems that this irregular spacing was produced through some of the leaves never becoming developed beyond the condition of closely adherent scales, as in the recent *P. neriifolia*, especially when individual leaves were large. The branchlets were short, truncated at the apex, with each year's growth marked off by an encircling scar or cicatrix, giving the stem externally a jointed appearance, common to almost all the living species of Podocarp belonging to the same group. The cicatrix is superficial, and leaves no mark of its presence in the interior of the wood, so that the branchlets do not always break up where they occur. The leaf-scars left on the stem are very ill defined, and the older bark merely looks stringy. The terminal bud (fig. 2) is relatively small. A complete shoot with only three leaves is represented on fig. 1. Those on fig. 3 are unusually small, and I should say from an examination of the dried specimens in the Kew Herbarium, that the

leaves were in this instance thin and not fully developed, for the same waviness discernible in the right-hand leaves of fig. 3 is visible in recent leaves pressed under such conditions.

As remarked by Prof. Olliver, who at once pronounced them to be Podocarps,[1] even were the specimens living it would not be possible to assign them with certainty to any particular species. There are in fact more than a dozen living Podocarps with very similar foliage, distributed in a great belt extending from Venezuela to Chili, the Cape and Tropical Africa, through Hindustan to Japan, and down to the Fiji Isles, New Caledonia, and Queensland. In nearly all these, the leaves, it is true, are usually arranged in whorls and are more or less tufted, and they also taper more to the base and possess longer foot-stalks; but in some of these species the leaves seem occasionally to revert to the distichous arrangement, and it is therefore not easy to say definitely that the fossil represents any one species to the exclusion of others. The most perfect resemblance is, perhaps, to be found in one of the specimens of *P. falcata*, R. Brown, at Kew, in which the leaves are almost sessile, broadest near the base, and in two rows. This is a native of the Cape and tropical Africa. Another species very closely resembling it is *P. Thunbergii*, Hook.; an immense tree known at the Cape as "Yellow Wood." Of the other species, most are large trees, and very few are hardy; but young plants of many of them are to be seen in cultivation in the Great Conservatory at Kew.

There are no other genera of Conifers with which it can possibly be mistaken. The regular and crowded arrangement, in two even rows, of the leaves of *Cephalotaxus* and *Torreya* suffice to distinguish them from it at the first glance. Its resemblance to some Bamboos is far more striking, though of course merely superficial.

Attention had already been called in this work[2] to the presence of *Podocarpus* in the Ardtun Beds. Scattered leaves are not very rare in the black shales, but their preservation did not admit of any description or further determination being hazarded. It cannot be identified with any of the numerous detached leaves that have been figured from the various Tertiary Leaf-beds of Europe. It best agrees with *P. hæringiana*, Ett. (*P. eocænica*, Unger, *fide* Heer), from Häring, and *P. eocænica*, described by Ettingshausen from Bilin, and from the Saxon Brown-coal, by Engelhardt. Its complete absence from all the Arctic Floras described by Heer, and from all the Cretaceous and Tertiary Floras of North America, is far more important, and probably a fact of some significance in the history of the existing distribution of plants.[3]

[1] Newberry, Carruthers, Britten, and other botanists who have seen the specimens or the plate are agreed upon this.

[2] Pp. 13, 48.

[3] "Only three or four species are sufficiently hardy for cultivation in this country, and these require warm and sheltered spots. Other species are noteworthy for their great value as timber-producing trees in their native countries, as the Totara Pine of New Zealand, the *Podocarpus cupressina* of Java, &c."—'Veitch's Manual of the Coniferæ,' p. 317.

The certainty that it is quite distinct from the typical *Podocarpus eocænica*, in which all the above-named specimens have been included, though perhaps erroneously, and from any others hitherto described, necessitates a new specific name, and I have therefore pleasure in naming it after the Duke of Argyll, to whose researches we were first indebted for our knowledge of the flora.

Detached leaves are not uncommon in the third or lowest bed at Ardtun. The fine specimens on Plate XXVI are preserved in a close-grained matrix not unlike the celebrated lithographic stone of Solenhofen, and are now deposited in the British Museum.

GINKGO ADIANTOIDES, *Unger*. Plate XXV.

GINKGO BILOBA, *Procacc.* Annali di Bologna, An. 1°, vol. i, 209, pl. iv, fig. 3, 1838.
SALISBURIA ADIANTOIDES, *Unger.* Synopsis, p. 211, 1845; Chloris Protogæa, p. lxxvii, 1847; Gen. et Spec., p. 392, 1850.
— — *Massal. e Scarab.* Flora foss. del Senigalliese, p. 163, pl. i, fig. 1, pl. vi, fig. 18, pl. vii, fig. 2, pl. xxxix, fig. 12, 1859.
— PROCACCINII, *Massal. e Scarab.* Id., p. 165, pl. xxxix, fig. 1, 1859.
— BOREALIS, *Heer.* Flora foss. arctica, vol. i, p. 95, pl. ii, fig. 1, pl. xlvii, fig. 4*a*, 1868.
— ADIANTOIDES, *Heer.* Id., vol. i, p. 183, pl. 47, fig. 14, 1868.

Basaltic Formation; Ardtun Head, Isle of Mull.

Leaves from two to four inches in diameter, broadly fan-shaped or flabelliform, somewhat resembling those of the Maiden-hair Fern, wedge-shaped at the base, leathery, more or less cleft into two lobes, smooth, undulating, and sometimes notched at the margin. Foot-stalk stout, equalling or exceeding in length the radius of the leaf. The veins not only spring or diverge from the base, but also from two strong ribs into which the petiole splits, and which border the lower sides of the leaf; the veins extend thence to the upper margin without diminishing in size, and are minute, dichotomous, equi-distant, and sub-parallel, forking as often as necessary to maintain their relative distances. Between these are quite disconnected, short, elevated, dotted, and spindle-shaped regions, discernible in the fossil, and mistaken by Massalongo[1] for parasitic fungi. These are best seen in the recent leaf by holding it to the light, when they appear trans-

[1] 'Flor. foss. del. Senigalliese,' 1859, p. 87, pl. i, fig. 1, *Sclerotites salisburiæ*, Massal. Saporta has suggested in a letter, and Mr. Murray of the British Museum has confirmed the view, that these are resin-chambers. They are referred to by Dr. Bary ('Vergleichende Anatomie,' English translation, p. 442):—"In the lamina of Ginkgo, in place of the uninterrupted canals, there are, between the vascular bundles, short cylindrical sacs, 1 mm. or more in length, which are closed blindly at both ends."

parent like the veins. The veins are very well defined and slightly elevated on the under side of the leaf (figs. 1 and 3, Pl. XXV), but less easily traced on the more wrinkled upper surface, figs. 2, 4, 5. The latter figures exhibit the undulations or folds such as are frequently seen in the leaves of the living tree.

The specimens from the newly noticed bed at Ardtun are far larger and better preserved than any previously found in Tertiary Rocks. In a layer of white clay at the base of the bed they are of a purple colour and massed together in the greatest profusion. The specimen (fig. 3) is from this layer and shows the texture, after maceration, to have been such that the venation of an immediately underlying leaf is distinctly visible through the one above.[1] They are much larger than the average in the living species, if we may judge from dried specimens and those in cultivation, but a garden variety has been produced in France in which the leaves often measure five and even six inches across.[2]

The Ginkgos are very large trees indigenous to China, where they seem, however, as yet to be unknown in a wild state. When stripped of their leaves there is nothing to indicate, externally, that they belong to the Coniferæ. The peculiarities of their internal structure and a brief sketch of their ancestry are described on pp. 45 and 122 of this memoir.

There can be no reasonable doubt about the specific identity of the Ardtun fossil and the living *G. biloba,* Linn., yet as only the foliary organs of the former are known, we should hardly be justified in making it an exception to the rule which has hitherto conferred distinct specific names on plants of Eocene age, no matter how great their resemblance to existing species may be. We can hardly admit the identity of the magnificent Scotch species with the starved Cretaceous form from Greenland, to which the name *G. primordialis*, Heer, was applied: but we cannot regard the British form as distinct from *Ginkgo* or *Salisburia adiantoides*, Ung.,[3] though the largest of the specimens figured by either Heer or Massalongo under that name do not equal in size those shown on Pl. XXV. When, however, a trinomial system is adopted, as must some day happen, its full name might well be *G. biloba hebraidica*, with the addition of *foss.* or *f.* for fossil, thus rendering any confusion impossible.

I had never heard that *Ginkgo* occurred in Mull, until I found a few imperfect specimens this year in the black beds of Ardtun; but its presence had long been known to the Duke of Argyll, who had, indeed, for many years, possessed a specimen in his Museum at Inveraray. It is, as already stated, abundant in the light-coloured beds of Ardtun, and the fact that this singular tree flourished within the British area in Tertiary times should be of some interest to botanists as well as geologists.

[1] The leaves, though leathery when freshly gathered, become relatively thin when pressed, and underlying leaves can be seen through them, as in the case mentioned above.

[2] Gordon's *Pinetum*, *S. adiantifolia macrophylla,* Hort., p. 375, 1880.

[3] It abounds chiefly, it appears, at Hare Island, a few miles north of Disco, and at Atanekerdluk. Heer has also noticed fragments from the grey clays of Samland, on the Baltic.

TAXUS CAMPBELLI,[1] (TAXITES, *Forbes*). Plate X, fig. 1; Plate XXVII, figs. 1—3.

Basaltic Formation; Ardtun Head, Isle of Mull.

The species was described at page 41 of this memoir from the unique specimen in the Museum of Practical Geology in Jermyn Street, as *Sequoia Langsdorfii*, Brong.; the figure (Pl. X, fig. 1) seemed to justify, or at least not to contradict, the universally accepted view promulgated by Heer as to its generic affinity with *Sequoia*. My personal researches in the Ardtun leaf-beds in the present year have, however, shown me that this accepted view is erroneous, and have upheld the correctness of Brongniart's and Edward Forbes's original determination. In justice to these most able observers, I embrace the opportunity of withdrawing a correction, which I am now convinced was unjustifiable. Unger, Weber, Goeppert, and others had repeatedly described twigs with similar foliage under the name *Taxites*, believing them to belong to the Yew or the Yew tribe; and nothing is more remarkable than the way in which authors permitted every yew-like twig of Tertiary age to be swept into the genus *Sequoia*, when we examine the evidence upon which the change in the nomenclature was based.[2]

There are many peculiarities in the Ardtun Conifer which are not met with in the Redwood, but are characteristic of the Yew, though they are perfectly indistinguishable, in either the fossil or recent state, by the actual form of the leaflets. Foremost among these is the fact that the foliage of the Redwood, shed in summer and autumn, breaks up and falls in the vast majority of cases as simple, unbranched twigs, many of which are very long, and comprise two or three years' growth. The Yew behaves quite differently, the majority of the twigs shed remaining compound. The specimens figured, as well as others, suffice to show that the fossil species by no means broke up in the manner of the Redwood, but distinctly after that of the Yew. Another character which can be detected in very few fossils, the stem being generally a more or less indistinct coaly mass, is the insertion of the leaves. In *Taxus* the base is constricted, almost petiolate, where it approaches the stem, swelling out again into a sort of cushion where it is adnate or embraces the stem;[3] while in *Sequoia* the constriction is more apparent than real, being chiefly due to the sharpness of the twist made by the leaf in becoming decurrent to the stem, and there is never any sort of thickening. In consequence of this the leaves are comparatively readily detached in the Yew, and most persistent in the Redwood.

[1] See *Sequoia Langsdorfii*, p. 41, for history and description.

[2] For many years all the yew-like foliage of the Tertiaries was determined as *Sequoia Langsdorfii*, and its presence, as in Mull, went far in giving the age of the beds as Miocene.

[3] The leaves clothing the branchlets, which are destined to remain attached for a long time on the Yew, become more and more constricted with age at the point of contact with the stem, until at last they become distinctly articulated and fall off, leaving the stem clothed with the scale-like bases of the leaves only. This never happens in *Sequoia*, where the whole leaf remains attached as a spiny scale until it decays away.

Though I had not noticed the peculiarity when I drew the enlargement (fig. 1, *a* on Pl. XXVII), I am sure that the fossil agrees with the Yew, and that the leaves have not the twist of *Sequoia*. Again, there is the absence of *Sequoia* cones in the beds at Ardtun; while, on the other hand, there is a small coaly disc in contact with the apex of the specimen, fig. 1, which might be a male flower or bud of *Taxus*, and an indistinct disc among the leaves of fig. 2, which might be a berry; I wish, however, to lay no stress on these. Finally, we have in the specimens a greater general resemblance to *Taxus cuspidata* and *T. adpressa* than we have to *Sequoia sempervirens*, specimens of the first-mentioned Yew, in the Kew and British-Museum Herbaria, even reproducing the little imbricated spike at the apex of fig. 2.

In addition to positive evidence, there is the negative fact that all the plants yet determined from the British Basalts are now indigenous, if still living, to Western Asia and Eastern North-America—among them being *Onoclea*, *Ginkgo*, *Cryptomeria*, *Podocarpus*, the *Cypress*, and *Pines*. *Taxus* would be at home in such company, while it is almost needless to say, *Sequoia* would not. Against this evidence there is nothing opposing to set. *Sequoia Langsdorfii* no doubt occurs in many places in Europe, but Heer's claims for it—perhaps in some cases put forward without an examination of the specimens themselves—were too comprehensive, and the species is in great need of revision.

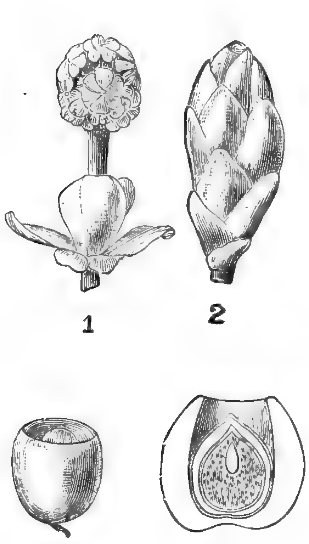

FIG. 38.—Fructification of the common Yew. (1) Male or staminiferous flower; (2) Female or ovule-bearing flower; (3) Ripe fruit; (4) Longitudinal section of the seed showing the position of the embryo. ('Veitch's Manual,' p. 296.)

It seems no longer necessary to retain the generic name "*Taxites*" in this case; for either the fossil is *Taxus*, or else some quite different Conifer. It cannot be identified with certainty with any of the many other European Eocene forms described as *Taxites Langsdorfii*, and there is no alternative but the pleasing one of restoring the specific name originally given to it by Edward Forbes.

Taxus adpressa, Knight, of Japan, is a dense, spreading, and depressed bush, seldom growing more than six or eight feet high. *Taxus cuspidata*, Siebold, which the fossil chiefly resembles, is described by Gordon as a large, handsome bush, densely clothed with somewhat ascending branches, and dark green foliage, growing from fifteen to twenty feet high, found in the Island of Jesso and to the South. Veitch describes it as generally solitary in the forests of this island, attaining a height of from thirty to forty feet, with a trunk from one and a half to two feet in diameter. The branches are spreading, and the general aspect is less dense than the common Yew, and with a somewhat more irregular outline. The leaves are broader, more abruptly pointed, more leathery in texture, and lighter in colour than those of the European species.[1]

[1] 'Manual of the Coniferæ,' p. 306, James Veitch and Sons, 1881

NOTES ON THE ADDITIONAL SPECIES OF CONIFERÆ.

As already remarked, the Eocene plant-beds were by no means exhausted when the description of the Coniferæ was undertaken. On the contrary, greater interest has been aroused, and, in addition to the grant made by the Royal Society, a Committee of the British Association has been formed to continue their exploration. The results of this assistance so far as the Coniferæ go are to be found on Plates XV to XXVII, and include many of the most satisfactory and finest specimens. Fresh discoveries have rendered it highly probable that all the Coniferous twigs and leaflets found at Reading and Croydon, though so varied in appearance, may really have belonged to a single dimorphic form of *Taxodium*, indistinguishable from *Glyptostrobus heterophyllus* of China and Japan. They could hardly have been placed in one species without such undeniable evidence as that furnished by specimens from Reading, which show the distinct kinds of foliage on the same branch. The abundant specimens of that singular extinct ally of *Agathis*, *Doliostrobus*, have been furnished by Mr. E. A'Court Smith, and a visit to Gurnet Bay has enabled me to reproduce the large specimen (Plate XXIII), by means of which, we are enabled to form a satisfactory idea of its habit of growth. But far the most important additions to our Coniferæ, are the fine species of *Podocarpus* and *Ginkgo* procured from the Isle of Mull, and which Prof. Newberry and others acknowledge to be the most beautiful fossil remains of these plants ever obtained. They are from a bed from which no collections had previously been made, composed of hard and very fine-grained cement-stone of a pale French-grey and buff colour, which was not described in detail when the Duke of Argyll referred to it as the lowest of three Leaf-beds, in 1851. The Irish Tertiary Basalts and plant-beds have been described in the preceding pages,[1] and it will be of interest to supplement them by an account of those of Scotland.[2]

The Scotch Eocene Basalts.—The position and contour of the beds at Ardtun Head, in Mull, were very fully described by the Duke of Argyll when the occurrence of fossil leaves among the Basalts was first made known. The Head faces Staffa and the Treshnish Isles, which are mere fragments of a once continuous sheet of solid rock that has been cut up and, as it were, dissolved away like so much sugar. As monuments of the resistless power of the waves no scene can be more impressive than this range of scattered islets stretching towards the Atlantic. Most of them appear as horizontal as the slate of a billiard table, and such sheets, extending for miles in every direction, show the overwhelming volume in which the Eocene Basalts must have been discharged. Directly opposite Ardtun, on the other shore of Loch Scridain, is the gigantic headland of Bourg, rising to a height of 1600 feet. This

[1] See p. 77.

[2] They will constantly be referred to in describing the Flora.

mass is composed of some four and twenty horizontal sheets of lava of great thickness, and furnishes the key to the position of the Ardtun and Staffa beds in the series, for Cretaceous and Jurassic rocks crop up at its base. The eruptive series commence with two great deposits of ash, each twenty or thirty feet thick, followed by some 100 feet of lava, the upper bed of which seems part of the flow forming the beautiful columnar beds of Ardtun and Staffa. An interval of rest followed, during which the fluviatile beds of Ardtun were deposited; these being represented at Bourg by nine to twelve feet of clays and sand without fossils. They are overlain by a bed of rudely columnar Basalt, identical with that which overlies the leaf-beds and forms the capping at Ardtun. Next is a bed of scoriaceous lava, thirty feet thick, which has caught up a few flints, and a bed seventy feet thick of remarkably compact lava. Above this again is about 1000 feet of lavas, some very much decomposed, with little if any intervening ash-beds, only a few thin beds of which reappear towards the summit.

It can hardly be doubted, in view of their great horizontal extent and vertical thickness, that nearly the whole of these lavas were formerly continuous, for no less majestic cliffs of the same composition form parts of coast lines east and west, and north and south. Time, however, has not spared them, and scarcely anything now remains at Ardtun and the Isles of all the long series of flows, except portions of two of the lowest and oldest sheets. The under part of the inferior of these is transformed into such columns as those which have made Staffa famous, though they are no less beautiful at Ardtun; while the upper one, imperfectly columnar and much fissured and jointed, forms still more precipitous and picturesque cliffs, presenting the appearance of ruined masonry. Sandwiched between these is a mass of sedimentary rock which reaches a maximum thickness of over thirty feet. A small chine or ravine marks almost the centre of the headland, and it was here that the Duke's published sections were taken. The eastern face is the more accessible and best to work, and it was at this spot that I decided to carry on somewhat extensive quarrying operations, whereby the following beds were penetrated. Resting upon the amorphous Basalt is a bed of carbonaceous rubble filling in the inequalities of the lava and about a foot thick, succeeded by two feet of indurated sand or grit. The true leaf-bed, the second in the Duke's section, follows; and though now a hard and brittle black shale, was originally a fine carbonaceous mud. It is two feet four inches in thickness, the lower part squeezed and without recognisable fossils; then a few layers containing numerous specimens of a simple ovate leaf;[1] another layer squeezed and with only macerated remains, and finally some layers made up almost wholly of large palmate leaves, known as *Platanites aceroides*. Overlying this, and distinctly separated, is a bed, a foot thick, of very hard whin-like rag, doubtless sandy carbonaceous mud when deposited, containing very large leaves of the so-called *Platanites*, with broken up fronds of *Onoclea* and *Equisetum*. The next bed is similar, marked off by a definite plane of bedding. It possesses few if any fossils, and passes gradually

[1] *Rhamnites*, Forbes, in the Duke of Argyll's Memoir.

upward into a mass of indurated gravel seven feet thick. In the ravine the gravel bed is externally as black as the lava, but fresh surfaces of the rock, shattered by blasting, showed a clear steely, French-grey matrix, with pure white flints so firmly cemented that the fractures had invariably passed through rather than round them. Here and there were stones of a cherry-red, and closer inspection revealed that many pebbles of almost the colour of the matrix had likewise been broken through. This pudding-stone, or indurated gravel, passes upward gradually into purer sand, eight feet thick, and comparatively soft and fissile at the top. The final parting between the sedimentary beds and the lava above is a rubble similar to that at the bottom.

This ravine proved, however, by no means the best spot, either for observation or collecting, though the most accessible. It appears in fact to be due to the weathering out of a dyke, now decomposed. The pressure of the upward passage of the incandescent mass has squeezed and distorted the plant beds and discoloured the gravel. The latter appears so altered as to have been mistaken for a volcanic agglomerate, but closer examination shows that it has the bedding of true river-gravels, and that all its materials are water-worn. Eighty yards farther east it has thickened to twenty feet, and the sand preserves its original colour. The current-bedding is beautifully shown, together with the drifts of shingly gravel and some small round boulders, so that no one could fail to recognise at the first glance its fluviatile origin. In addition to the leaf-beds at the ravine already described, which are continued unchanged, we find underneath, in descending order, a second gravel bed, of finer grain, three feet thick; two feet of grey clay with larger leaves in the rust-coloured partings; six inches hard laminated gritty sandstone with leaves; three inches hard lavender and buff cement-stone with very well-preserved leaves; one foot grey clay, with a thin layer at the base, literally choked with leaves in fine preservation, but very difficult to remove; six to nine inches clunch, inclined to be concretionary, with rootlets; and lastly, a thin layer of carbonaceous matter and grey clay filling in the inequalities of the old lava surface. There is a considerable variety of leaf in the lowest leaf-bed, but the most striking and abundant are those of *Ginkgo*. In addition to the dyke now weathered out, the Head has been traversed by an extensive sheet of Basalt, which has forced a devious way upward at a low angle through the series; and this also, owing to denudation, comes to the surface at the ravine. It is twenty to thirty feet thick, readily distinguished by its superior hardness and density, and finer grain; and it obliterates the sedimentary beds for some distance where it crosses them. The gravel, however, soon reappears; and where last seen, at a distance of 700 yards from the ravine, is still twenty feet thick. The fluviatile series is therefore of considerable extent, and its importance has been much underestimated. It is now known to occur at Carsaig on the other side of the Ross of Mull, at Bourg, and in Loch Na Kael, and it will be interesting to trace its limits in other parts. Though the gravels are unfossiliferous at Bourg, a large tree,[1] with a trunk five

[1] The wood is carbonised, and charred. Mr. Healy has kindly examined it microscopically and pronounces it Coniferous; and Mr. Carruthers thinks it might possibly be a trunk of *Podocarpus*.

feet in diameter, has been enveloped as it stood, in one of the underlying lava-beds. Owing evidently to its solidity and substantial girth, it resisted erect the fiery embrace of a torrent of molten and liquid lava forty feet in depth, for the outer layers are still preserved; but subsequent prolonged exposure to damp and wet, acting from above, slowly rotted the heart-wood, until little of the trunk remained beyond a cylinder or well choked with rubble. A little further on lies the limb of a great tree, which, long before the Ardtun river flowed in this direction, had helped with other débris to fill in a fissure.

The examination I have made of the area surrounding the Ardtun leaf-beds, has convinced me that these latter are stratigraphically much nearer the base of the Basalts than the corresponding plant-beds of Antrim. Having regard to the greater thickness of the series in this part of Scotland, and especially to the presence of extensive ash-beds at its base, it is difficult to come to any conclusion other than that the Ardtun beds are the oldest; and the opinion I had formed as to the relatively greater antiquity of the Irish plants must thus be accepted with reserve. As far as its bearing on geology goes, my work on fossil plants is for the present, and probably must be for some time to come, destructive rather than constructive.[1] Stratigraphical and physical evidence helps us but little in these vast volcanic regions, and nothing but the most patient investigations will ever bring the débris of plants, so wonderfully preserved in them, into line with other organic fossils and make them acceptable to the geologist as trustworthy indications of age. Our greatest hope of success lies in continually checking them off by the fossil floras of the South of England, where the entire series of beds which make up the great group or formation called the Eocene is displayed in a compass that not only renders their study easy, but makes it certain that they are not separated from each other by very great intervals of time. The age of each of the plant-beds included in this series is as absolutely known as any fact of geology can be, for it is checked in every case by the intercalation of deposits, teeming with marine and estuarine Mollusca, which are acknowledged by everyone to be conclusive proofs of age. The discovery in the lowest of these beds of types of plants which, until now, have been believed universally to occur only in the Miocene would alone have rendered a complete revision of the whole subject necessary.

The explorations and quarrying operations in the Ardtun beds were carried out by means of a grant from the Royal Society.

[1] I am able to state that certain plants are not peculiar to the stages they are believed to characterise, and hence that the ages of many plant deposits have been determined on erroneous premises. I have reason to believe that other plants are absolutely confined in some areas to beds of very different age to what has been hitherto assumed, and that many plants from different areas, believed to be identical, are really not so. But I cannot yet claim that fossil Floras offer evidence of age of the same value as fossil Faunas.

RETROSPECT.

HISTORY OF THE GYMNOSPERMS.

The imminent publication of more than one work on the evolution of plants led me to defer the detailed sketch of the history of the Gymnospermæ, which would have found an appropriate place in the Introduction to the present volume. Viewed from an evolutionary standpoint the Gymnospermous plants assume an importance out of all proportion to the position they occupy in classifications based on living plants, or to their numbers and variety at the present day. They comprise and reveal to us many of the stages traversed between the Cryptogam and the Angiospermous Phanerogam, and alone bridge over the vast interval between these most widely separated divisions of the vegetable kingdom.

In endeavouring to trace the stages through which the progressive evolution of plants has been accomplished, we must beware of assuming that every less complex organisation is necessarily of greater antiquity than all those which are more highly developed. Combinations of circumstances exceptionally favorable to certain groups of plants have sometimes forced on their development to a state never afterwards surpassed, but which, on the contrary, may have retrograded by the dropping out of prematurely developed types. New series, however, have perpetually branched off to replace those eliminated, and the great vegetable kingdom has thus, as a whole, uninterruptedly progressed.

Before quitting the Coniferæ it is necessary, in order to make clear the relative position in a progressive series which they occupied, to say a few words on the lower forms of vegetative life. The study of the British Tertiary Flora has so far thrown little additional light on the evolution of the Coniferæ, and the present brief sketch of their past history is therefore mainly compiled from the works of other and more distinguished authors, to whom I take this opportunity of expressing my deep obligations.[1]

[1] I am greatly indebted to Prof. W. C. Williamson, who has kindly revised the sheets relating to Palæozoic plants, and for the use of his numerous and most valuable papers on Carboniferous plants in the 'Philosophical Transactions of the Royal Society;' to Mr. Carruthers for his many valuable suggestions and the information contained in his numerous works on fossil plants; to Saporta's magnificent work in the 'Paléontologie Française,' 2me série, "Végétaux fossiles," on the Plants of the Jurassic Formation: and Saporta and Marion's "Evolution du Règne Végétale," Phanérogames, vol. i, 'Bibliothèque Scientifique Internationale,' 1885. The full details of the theory of plant evolution, which I have attempted to sketch, though with considerable modification, are given in this work. The information derived from these authors is the basis of so much that I have written in these pages, regarding the older plants, that a general acknowledgment of my indebtedness to them must suffice.

I have also extracted much information from Bentham and Hooker's 'Genera Plantarum;' Sach's 'Text-Book of Botany;' various papers by Sir William Dawson; Schimper's 'Paléontologie Végétale,' &c.

It is well known that the lowest of all forms of life may be equally relegated to either the animal or vegetable kingdoms. These, the Protista are either amorphous or composed of cells filled with protoplasm, a complex living substance endowed with internal forces conferring upon them variability, in other words, vitality. It is not improbable that the earliest primordial plants may have possessed no higher organisation than this. There are dredged, say Saporta and Marion, on the southern shores of France, creatures several centimetres in length, whose substance is entirely penetrated with fine particles of the sea-bottom. They would pass unnoticed did they not shift their position with extreme slowness and vary their form by the extrusion and retraction of short prolongations. Placed in a glass of sea-water they attach themselves to the sides, and free themselves gradually of sand, when a slightly yellow hyaline jelly, absolutely deprived of nucleated elements, is disclosed. They are allied to the *Protamœba* and *Pelobius,* and from these starting-points all the progressive stages of development are traceable.

In certain of the Protista cellulose envelopes are developed, and when further certain portions of the protoplasm become separated and assume a green colour, and are thereby converted into chlorophyll, all the characters of vegetable life are realised. The presence of this special substance gives rise to a whole series of new physiological functions; though present in some animals, it essentially characterises vegetable life. A principal distinction between the two kingdoms is thus due at the outset to the transformation of part of the elementary protoplasm into granules of chlorophyll.

In progressing upward the structure of plants becomes increasingly complex, and a nucleus appears in the cells. By gradual stages the Protophytes or Thallophytes are reached, including the single-celled Desmids and Diatoms, with hard or soft envelopes, the Confervæ, Fucoids, the higher Algæ, Florideæ, and Characeæ. The Fungi are destitute of chlorophyll, and hence, or owing to their parasitic and saprophytic habits, any further development in them seems to have been arrested.

While the more highly organised and complex Algæ have retained the aquatic habits necessary to their existence, some forms of *Nostochineæ, Palmelleæ,* and *Vaucheria,* seem from time to time to have quitted the water to occupy humid places on land. These furnish the earliest indication of adaptability to aërial life; and it is curious to find this proceeding from the lower types, but slightly differentiated from each other morphologically, rather than from the higher types of Algæ. Saporta and Marion assume that when dry ground appeared some of the lower Algæ with flat cellular fronds, such as *Ulva,* gradually took possession of damp or marshy spots and, creeping face to the ground, became ancestors of the Hepaticæ;[1] while others, more confervoid and possessing a thallus with apical growth, have increased in complexity while adapting themselves to subaërial

[1] This is merely conjecture. Prof. Williamson, who has kindly looked through the proofs, reminds me that the Hepaticæ possess a thallus with apical growth (see Sachs, p. 347), and he has plants of *Metzgeria furcata* showing it.

conditions. Foliar appendages were probably given off, and a sort of plantlet with strictly cellular root-like and leaf-like organs would thus have come into existence, capable, like the Mosses of the present day, of agamous reproduction. Such a primordial cellular plant constitutes the first stage of growth, not only of Mosses and Hepaticæ, but also of Ferns, Equisetaceæ, Lycopods, and Ophioglosseæ. They are developed from the spore and closely resemble the lower Algæ in their purely cellular structure.

Saporta and Marion also regard the relatively early or late appearance of sexual organs in the life of a plant as exerting a predominant influence on its susceptibility to become differentiated or modified through the force of the changing circumstances which surround it. Those among the primitive terrestrial Algæ in which sexuality was deferred until late had a longer period of purely vegetable life ; and were thus not only more susceptible to the influence of new conditions, but had a longer time in which to adapt themselves to them, and so become diversified in type. Among the results of this elaboration they place the existing Mosses and Hepaticæ. In the Mosses the spore gives birth to a conferva-like thallus, called the Protonema, a reversion in all probability to a primitive ancestral stage. The growth of this elementary thallus, or purely cellular plant, is never arrested by the development of sexual organs, and is thus peculiarly susceptible to differentiation ; foliar buds are given off in places from its ramifications,[1] the increase of cells at these points assumes a regular plan, and little by little small laminæ take the form of leaflets borne on a stem supported by radicles. These radicles are capable of producing new plants and propagate so energetically that extensive carpets of moss may be formed without the aid of reproductive organs, which, indeed, are rarely present in some species. When present, however, they are of great morphological importance, and are distinguished as male, or "antheridia," and female, or "archegonia." The male is generally a club-shaped body, attached to the stem, filled with small and crowded cells, each of which contains an antherozoïd. The female organs, when mature, are in shape of a flask with a long neck, bulging from a narrow base and composed of a number of cells, of which the central, basal one is the largest and develops the oospore. At maturity the antherozoïds escape by the rupture of the antheridium and enter the archegonium. A new plant is produced by the oospore, which develops within the archegonium in which it is born and finally becomes the stalked organ called capsule or fruit in the Mosses. This so-called fruit bears no resemblance morphologically to the fruit of a Phanerogam, but is in reality a distinct asexual generation or separate plantlet, called by Sachs a "sporogonium," which gives birth to the spores ; which spores, falling in damp places, give rise to a new sexual generation of thallic, or moss plants. This alternate generation is unknown among Algæ, and the Hepaticæ and Mosses therefore introduce a new point of departure, the more developed and conspicuous of the two generations being very analogous to Algæ, while the less conspicuous sporogone is agamous, subordinate, and incapable of disengagement from the archegone in which it is formed ; yet it is fundamentally an independent plant. The

[1] Most frequently from the root-hairs, according to Williamson.

Hepaticæ are similar in growth, and, with the Mosses, present a stationary group which has elaborated a special kind of differentiation, but, since evolution has acted exclusively on the first generation, in a direction limited by biologic conditions.

Some of the vascular Cryptogams, as the Ferns, Equisetaceæ, and Ophioglosseæ, present a further stage of development. Their life-history, as in the Mosses, is divided into two generations which are extremely different, not only morphologically but physiologically. Their spores give rise to a cellular thallus or "prothallium," never differentiated as in the higher Mosses into a stem and leaf, but producing sexual organs, namely, archegonia and antheridia. The sporogone, or young plant of the second generation resulting from the fertilisation of the archegonium, instead of remaining a mere fruit-like appendage of the sexual plant, as in the Mosses, is vigorous and independent, and speedily supplants the ephemeral parent prothallium. As soon as free it takes root and finds its own nourishment; its tissues become extremely diversified, and fibres and vessels, histological elements previously unknown, are developed, and plants known as Ferns and Horse-tails result. In some of these the spore-producing generation, or sporogones, attain great age and very considerable dimensions, as in Tree-ferns; but on the leaves of all alike spores are born whose germination produces a new generation of humble cellular prothallia. The vast preponderance of this new vegetative system, the sporogone, is already manifest, and in the next grade of plants we shall see that the independent sexual generation is still more effaced.

In the Rhizocarpeæ, Selaginelleæ, and Isoëteæ, a yet further step towards the evolution of the highest plants, the Angiosperms, is made, for the separation of the two sexes is foreshadowed in the two kinds of spores which they produce.

Of these the *macrospores* are female, for they develop a prothallium bearing exclusively female organs; and the *microspores* male, inasmuch as their smaller prothallia only bear male antheridia. In the Rhizocarps distinct progress is made towards the suppression of the sexual generation, for the female prothallium is so reduced that the sporogone appears to be almost directly disengaged from the macrospore. Merely a small appendage remains formed and nourished in the macrospore, and with only a very small external development. In the sporogone of the Rhizocarp a "sporocarp," or kind of fruit, appears, which is formed through the differentiation of some of the fronds, and contains both micro- and macrospores enclosed in sporangia; in Marsilia this fruit reaches the highest point of complexity to be met with in existing Cryptogams. The Selaginellas and Isoëtes present an equal development, for the prothallium is retained within the macrospore itself as a mass of cell-tissue, in which true archegonia appear, destined to receive the antherozoïds on becoming exposed by the rupture of the cell-wall of the spore. In the microspores the male prothallium is a wholly rudimentary organ reduced to a single vegetative cell without function, and apparently a useless appendicle to the antherozoid-producing cells which accompany it. To complete the metamorphosis to Phanerogams the only further step required is that the macrospores should be fertilised

in situ on the plants; and already in the plants last described they have a tendency to become less readily detached than the microspores. This stage may have existed among the extinct allies of the Selaginellas, and we shall meet with it in the Gymnosperms.

The alternation of generation which is so eminently characteristic of the Cryptogams takes place within the seed of Phanerogams. The second generation, which is absent altogether in Algæ, and so inconspicuous in the Mosses that it never develops beyond the fruit-like cup in which the spores are produced, preponderates in the Ferns, whilst in the Gymnosperms the first generation is so completely hidden that it never emerges from the seed. We have thus seen that, if we omit the Fungi, the progress of evolution, from the simplest cellular plant to the most complex vascular plant, required that reproduction by sexual functions should be accomplished during a certain stage by means of a separate and special generation. The first trace of such a dual generation is to be found in the capsule of the Mosses, where the second generation is rudimentary, and has no separate existence. A host of intervening forms must have disappeared between this and the next group, the Ferns, for in these not only is the second generation thoroughly distinct, but the first has sunk into a short-lived and humble cellular plant, while the second has developed into a magnificent vascular plant which sometimes attains tree-like proportions. The first generation, now subordinate, is soon destined to disappear altogether, and in the Rhizocarps, as already mentioned, a vast stride is made towards this consummation. Two separate kinds of spores are produced, in the larger of which the once independent first generation appears as an inclosed cellular mass within which the female organs are developed, so that practically the larger spore has become a seed. With the next step in the progress of evolution, the slender line dividing Cryptogams from Phanerogams is crossed. The Cycads are the nearest on the other side of this dividing line, and in them germination takes place in the macrospore or seed, while it is still attached to the plant, instead of after it has been shed.[1]

Before passing on, however, to the true Gymnosperms, we have to notice a consider-

[1] Before dealing with these it is well to become familiar with the terms used by botanists in speaking of the organs of Phanerogams, which are different from those used for the functionally corresponding organs in Cryptogams.

Cryptogams.		*Gymnosperms.*
Archegonium.	Equivalent to	Corpuscle.
Antheridia.	,,	Anther.
Thallus and Prothallium.	,,	Endosperm (part of the seed).
Sporogone.	,,	Plant.
Microspore.	,,	Pollen-grain.
Macrospore.	,,	Embryo-sac, oosphere, the germinating cell (part of the seed).
Microsporangium.	,,	Pollen-sac.
Macrosporangium.	,,	Ovule.
Spore-bearing leaves.	,,	Stamens and carpels.

able group of extinct Carboniferous plants which united the characters of the Lycopodiaceæ and other Cryptogams with true exogenous stems. Though not in the direct lines of evolution, for the truly Gymnospermous *Dadoxylon* equals them in antiquity, they probably reveal the lines through which the passage from Cryptogams to Gymnosperms has taken place. Believed by Brongniart, Grand'Eury, Renault, Saporta, and Marion to have been Gymnospermous trees, they have been the subjects of prolonged discussion and research. The laborious investigations of Prof. Williamson had gradually made it clear that their peculiar exogenous growth was shared by the undoubtedly cryptogamous Lepidodendron, and the confirmation by M. Zeiller of Goldenberg's discovery that Sigillaria had spore-bearing strobili, has now confirmed Williamson's contention that they must be classified with Cryptogams.

As the earliest connecting links between Cryptogams and Phanerogams their morphology is peculiarly interesting, and the exquisite preservation of many of their silicified or calcified stems permits the minutest details of their structure to be studied.

That Cryptogams reached a far higher stage of development in the Palæozoic time than exists in any surviving representatives has not been disputed. One of the best known of these is *Lepidodendron*, the vigorous and splendid growth of which formed one of the culminating developments of the *Lycopodiaceæ.* The complex organisation possessed by them, even to the minutest points of internal structure, is very remarkable. "They formed large trees with acicular or falcate, perhaps, at a late period, deciduous leaves, and bore cones at the extremities of the branches, which differed exteriorly but little from those of some Gymnosperms. The expanded bases of the scales or bracts bore the sporangia, those containing the macrospores being nearest the base of the cone. In all the species the stem consisted of several layers. In most the centre consisted of a parenchymatous pith. In some this pith was only represented in its young state by one or two isolated cells, but these rapidly multiplied, developing into a conspicuous medulla. In one or two others these medullary cells were replaced by a solid rod of scalariform or barred Tracheids. In a third type barred Tracheids were developed within the cellular medulla—but at the periphery of the latter they rapidly coalesced into a vascular cylinder. In another type this cylinder was developed *pari passu* with the medulla, the boundary-line between the two being sharply defined. In all cases the vascular bundles proceeding to the leaves were composed of barred Tracheids derived from this primary vascular cylinder, the vessels of which were never arranged in radial lines. Even in its youngest state the bark investing this primitive, non-exogenous, vascular zone exhibited three layers—an inner, often delicate parenchymatous one, a median prosenchyma, which ultimately attained to great thickness, and a permanently thin superficial parenchyma.

"In most *Lepidodendra* there was developed, sooner or later, a second and more external vascular zone, the vessels of which were arranged in radiating laminæ and which was unmistakeably an exogenous development from a Cambium layer.

"*Lepidodendron,* like the greater part, if not all, of the Palæozoic Flora, became extinct

during the Permian period, leaving *Selaginella* and *Isoëtes* as its humble surviving representatives.

"*Sigillaria* closely resembles *Lepidodendron* in its organization. As in the latter, its exogenous vascular zone is richly supplied with medullary rays through some enlarged and symmetrically arranged forms of which the foliar vascular bundles, wholly derived from the inner non-exogenous vascular cylinder, pass obliquely upwards and outwards, on their way to the leaves."[1]

Professor Williamson describes the prosenchymatous and the parenchymatous structure investing the woody zone as a bark, and remarks that, although not divisible into layers identical with those of the Phanerogams, the enormous development of the elongated prosenchymatous fibres, or bast-tissue, in the interior of the fossil stems is a manifest foreshadowing of the presence of that same tissue in the bark of living exogens, especially the Cycads. There is no difference of opinion as to the exogenous nature of the second or outer vascular cylinder, though it bears a relatively small proportion to the diameter of the stem, nor as to the presence of representatives of medulla or pith, and bark; but while the French School, including Adolphe Brongniart, B. Renault, Saporta, Marion, and Grand'Eury, class *Sigillaria,* in consequence of its exogenous wood, as a low form of Exogen, Mr. Carruthers, Sir J. D. Hooker, Prof. Williamson, and many of the German authors have always regarded it as a highly-developed Cryptogam. It appears from Williamson's long-continued researches that the exogenous wood is not always developed in the young stages, either of *Sigillaria* or *Lepidodendron,* and that there is a gradual passage from one to the other. Sir W. Dawson, a great authority on the subject, now believes that some *Lepidodendra* are exogenous, and Prof. Williamson considers that eventually all may be found so.

The roots of these plants are known as *Stigmaria,* and are looked upon by the French School as rhizomes, capable of bearing leaves as well as roots, but as merely roots with rootlets by other observers. The erect and cylindric Sigillarian stems were crowned with a mass of long and linear leaves, whose scars have impressed their complex and beautiful tesselated designs on the trunks.

The next type of exogenous stem is still more remarkable, and its importance as one of the connecting links between the Cryptogams and the Gymnosperms cannot be overestimated. *Calamodendron,* of Brongniart, but which Carruthers and Williamson affirm is merely another name for *Calamites,* possessed a hollow stem with verticillate leaves, somewhat resembling a gigantic Equisetum. This was filled in solid with pith or cellular parenchyma when extremely young; but soon becoming hollow with age, the fistular interior consisted at last of a vertical series of oblong chambers, separated from each other by transverse diaphragms, and lined with a very thin film of cells. The exogenous zone, the presence of which has led to *Calamodendron* being classified by French authors with

[1] This description of the structure of the stems of *Lepidodendron* and *Sigillaria* has been kindly furnished by Prof. Williamson, to whom I am deeply indebted for it.

the "Progymnosperms," consisted of numerous woody wedges separated from each other, in the younger states, by peculiar vertical prolongations of the pith, to which Prof. Williamson assigns the name of primary medullary rays, while his secondary medullary rays separate the constituent vascular laminæ of each wedge as in recent Exogens. The wedges extended vertically from node to node, and their apices or inner faces originated in a vertical duct or canal. Investing this woody zone, and very rarely preserved, was a cellular layer without vessels, the structure of which is, as yet, but imperfectly known. In the young state it consisted of a thin layer of parenchyma composed of cells of various sizes. At a more advanced stage of growth these developed a thick internal prosenchymatous layer like that of *Lepidodendron* and *Sigillaria.* The outer surface appears to have been smooth, not fluted longitudinally, and the articulations to have been inconspicuous. The exogenous wood thus surrounded the pith, and somewhat resembled, in its arrangement, the first year's shoot of a recent Conifer. The rootlets (formerly called *Primularia*) grew from near the nodes and were branching. The arrangement of the appendicular organs on the young trunks was verticillate, and the leaves or branchlets were distributed at regular distances on the line of nodes, which were pretty close together, but the branches became few and irregular in older stems. Though there is no direct proof that such is the case, Saporta and Marion hazard the opinion that the foliage known as *Archæocalamites* and *Bornia,* which consists of repeatedly dichotomosing or acicular leaves, arranged in verticels around nodes, on slightly striated stems, belongs to *Calamodendron,* together with a male inflorescence born in catkins something like those of *Taxeæ.* Sir William Dawson states that he has found, on the other hand, the leaves attached to the stem in five species of *Calamites,* and in such relations as to give satisfactory proof as to their nature; and has shown that they are similar in form and external markings to the so-called branchlets of modern *Equiseta.* The fact is there is much difficulty in determining the true relations which the verticillate leaves of *Asterophyllites*, *Sphenophyllum*, and *Annularia* bear to their several stems.[1] Prof. Williamson has described a homosporous strobilus which he thinks belonged to *Calamites;* whilst he has found both homosporous and heterosporous ones which belonged to other allied Asterophyllitean plants. Saporta and Marion call attention to the resemblance between the leaves of *Bornia* and those of *Trichopitys* and *Bryon,* which are true *Salisburieæ;*[2] for, though the former are verticillate and the latter spiral in arrangement, the possibility of an easy transition from one to the other is shadowed forth in some Lycopods, and both dispositions occur together in existing *Cupressineæ* and the young *Abietineæ.*

Another remarkable Carboniferous stem with exogenous wood is described by Prof.

[1] Prof. Williamson remarks that "the structure and true relations of the roots and leaves are, as yet, the least known part of the history of Calamites." Very different looking organs occurring *in sitû* at Saint-Etienne are figured as roots of *Calamites* and *Calamodendron* respectively, 'Mem. de l'Acad. des Sciences,' 2nd series, vol. xxiv.

[2] [*Salisburieæ*—a family proposed to receive the numerous extinct as well as the solitary living species of Ginkgo.]

Williamson as *Astromyelon*. It appears that the stem and branches grew together in exactly the same relation as those of an ordinary exogenous tree, the branching not differing materially in its outward appearance from that of a Pine. He considers it a Cryptogam whose affinities were possibly with *Marsilea;* and that the large radiating lacunæ of the bark show that it was at least semi-aquatic in its habits.

Contemporaneous with these were many varieties of truly gymnospermous stems. M. Renault finds that the wood of *Poroxylon* is dotted with areolated puncta similar to those distinguishing the spiral vessels of Cycads and Araucarias; and Sir W. Dawson has described no less than five species of the Coniferous *Dadoxylon* from the American Middle Devonian. Prof. Williamson long ago demonstrated that the supposed British plants known as *Sternbergiæ* were merely inorganic casts of the hollow discoid pith of a *Dadoxylon*, and he has more recently shown that in some of these *Dadoxylons*, double foliar bundles pass off to each leaf-petiole, as in the recent *Ginkgo* or *Salisburia*. That the Gymnospermæ had already attained a considerable numerical development in the Carboniferous Period is still more apparent from the seeds met with in certain localities. The affinities of *Trigonocarpus* with the drupaceous seeds of the existing *Ginkgo* were pointed out by Sir J. D. Hooker and Mr. Binney as long ago as the year 1855.[1] Mr. Carruthers, in 1872, figured two species of *Cardiocarpon* attached to their axes,[2] and clearly pointed out their Gymnospermous character. The fortunate discovery by M. Grand'Eury of a number of silicified seeds at St.-Etienne and Autun; and the magnificent posthumous work upon them of M. Ad. Brongniart, completed by M. Renault, has shed a flood of light upon the subject. These seeds have been placed in a number of genera, and are of many and diverse forms, but as yet it has not been possible to allocate them definitely among the previously known Carboniferous genera. Prof. Williamson, in describing a large series of similar seeds from the Carboniferous deposits of Lancashire and Burntisland, seems to have experienced the same difficulty.[3] Some of them are more complex than those of many existing Gymnospermous seeds, those provided with a testa and a double membrane recalling seeds of Cycads and Taxeæ, especially Ginkgo. Notwithstanding their divergence of form, from simply bicarinated to a structure composed of many radiating elements disposed round a common axis, they have one peculiarity in common, the possession of a cavity at their micropylar extremity, called the "*chambre pollinique*" by Brongniart, and the "lagenostome" by Prof. Williamson. Pollen grains, sometimes much larger than those of existing Gymnosperms, entered this chamber through the micropyle, increasing in size during their stay in it and developing septa or cell-walls internally. Underneath this, the lagenostome or chamber, is the albumen or endosperm. Germination has not taken place in any of the fossil seeds and the development of the embryo is unknown. The great importance of these seeds lies in the fact that

[1] 'Phil. Trans.,' vol. cxlv, part 1, p. 149.
[2] 'Geol. Mag.,' vol. ix, pp. 55—57, figs. 1—3.
[3] "Eighth Memoir on the Organisation of Fossil Plants of the Coal-Measures," 'Phil. Trans.,' vol. clxvii, 1877, p. 213. M. Lesquereux has figured a number of similar seeds from the American Carboniferous.

their structure reveals, more clearly than do any existing seeds, the passage from the cryptogamic stage whence these early "Progymnosperms" had, so to speak, then but barely emerged.

Even the pollen grains themselves are not without interest when viewed from an evolutionary standpoint. Unicellular in Angiosperms, bi- or tri-cellular in Gymnosperms, they are seen to be distinctly pluri-cellular in "Progymnosperms," for the subdivision into many cells is said by Saporta and Marion to be discernible in all the silicified pollen grains of Carboniferous age yet studied.[1] The included male prothallium is supposed to be represented by the cells, and in that case has become merely rudimentary. Their relative size, reaching to half a millimètre, is remarkable, for this exceeds eight and a half times those of the Larch, the largest among living Coniferæ and twelve times those of Cycads and *Ginkgo*. But whatever the size, they are seen to have been divided into eight, twelve, or eighteen cells, the dividing septa of which are still perfectly visible. A considerable increase in bulk accrued to them, as we have seen, during their sojourn in the pollen chamber of the seed they had entered; while the female organ progressed simultaneously with the development of its *Corpuscula*, upon whose completion impregnation depended. That these cells are really the homologues of a rudimentary male prothallium has frequently been suggested, and it is due in a great measure to this structure and the position and development of the pollen-sacs, that Gymnosperms are admitted to occupy an intermediate position between vascular Cryptogams and Angiosperms. To this progressive and gradual obliteration of the independent sexual existence, characteristic of vascular Cryptogams, the evolution of Phanerogams is mainly to be traced.

Next, however, in relative development to the Dadoxyloid groups stands the "Progymnospermous" group or genus *Dolerophyllum*. This group deviates more or less considerably from the types we have hitherto considered, and in it we may hope to find the more immediate ancestors of true Gymnosperms.

The *Dolerophylla* were arborescent plants of large size, provided with leathery or thick, broadly ovate or orbicular leaves, with simple outer margins, but notched or auriculated inferiorly, sessile, and leaving a transverse scar of attachment on the stem which they closely embraced. These leaves were of considerable size and shed either singly or adhering to branches. They have been found principally at St.-Etienne, and also in the Permian of Russia. The leaves and branches were produced in great conical buds with convolute vernation. The veinlets are crowded, radiating, and dichotomous.[2] The lower epidermis was dense and provided with stomata, while embedded in the parenchyma and covering the veinlets are several rows of large elongated cells which contained gum or resinous sap. The organs of fructification are still incompletely known, but the

[1] Prof. Williamson thinks that the supposed cells may be but modifications of the sculptured extine.

[2] The veinlets are said to possess a duplex structure characteristic of the "Progymnosperms" and now only retained by the *Cycadaceæ*.

pollen-sacs were, according to M. Renault, disposed radially in double ranks upon, and partly embedded in, the surface of a not greatly modified peltate leaf. The pollen grains were very large, formed of many nearly equal cells, and doubly dehiscent longitudinally. The female organ, discovered by M. Grand'Eury, is an orbicular, scarcely metamorphosed leaf, hollowed in the centre to receive a single oval seed. In this primitive type the pollen-sacs are evidently homologues of the microsporangia of vascular Cryptogams; the pollen grains are the microspores, while the seed corresponds to a macrospore, germinating in position, and supported on a carpellary leaf.

Next to *Dolerophyllum* must be ranged the still more imperfectly known *Cannophyllites* of Brongniart, a plant with large leaves cut up into numerous segments, with median veins and numerous oblique veinlets, recalling leaves of *Scitamineæ*. In *C. Virleti*, Brongt., the leaves must have measured several feet in length and the stems have been also of great strength. Their nearest affinities are believed to be with *Psygmophyllum*, a prototype of *Ginkgo*.

Still more developed, and far more perfectly studied, are the CORDAÏTES. This important group first appears in the Carboniferous and did not outlast the Permian, its extinction seeming at once to make way for a great development of the true Gymnosperms. They were large trees, varied, distributed into many genera, and possessing characters common to the Cycadaceæ, Taxeæ, and Gnetaceæ, yet being as a whole inferior to true Gymnosperms; a group developed rapidly, and which has left no direct descendants. The stem was large and repeatedly branched, and in some cases bore leaves several feet in length. The leaves were coriaceous and possessed a multitude of equal subparallel veins. Three different types are known and are placed in separate genera, the commonest form being relatively broad and blunt at the end. The leaf-scars are transverse and discoidal, or bent and elliptic, and disposed in quincuncial order on the stem. The simple, or rarely composite fruit-spikes, furnished with spikelets in two rows, occur among the leaves without definite order. The stem was composed of a central pith; a woody region possibly identical in some cases with plants described under the name *Dadoxylon;* and a thick cortical region, divided into an inner parenchymatose, and an outer denser zone, traversed by fibrous cells and resinous canals. The reproductive zone was at the inner periphery of the cortical region or bark, and corresponded with Cycadean and certain monocotyledonous stems, rather than to those of acicular-leaved Coniferæ. The leaves had the progymnospermous structure which is still retained in the Cycadaceæ. The male and female organs were inserted in the axils of bracts on a floral spike. In the male the axis is short and furnished with bracteoles, and carries a number of staminal leaves either in a terminal cluster, or else spirally disposed. The staminal leaves bear three or four erect and terminal pollen-sacs, corresponding morphologically to microsporangia. The pollen grains contained in them are large and elliptic, composed of a finely reticulated integument that splits longitudinally, and an endospore composed of as many as ten cells. In the female, carpellary leaves corresponding to

Macrosporangia take the place of the staminal ones, each containing a macrospore clothed in a double membrane, similar in construction to seeds already described, and more complex than those of any existing Conifer. The *Cordaïtes* were the most developed of the extinct "Progymnosperms," and nearly equalled true Gymnosperms in the relative perfection of their organism. Though highly specialised, this betrays a decided approach to *Ginkgo*, not only in the form of the leaves, which are broad, blunt, and sometimes bilobed, but also in their organs of reproduction, more especially the seeds named *Cardiocarpus*, which almost exactly reproduce those of *Ginkgo*.

The "Progymnosperms" are not entirely extinct, for one order, the Cycadaceæ, has survived with little variation to the present day, and the living species preserve, almost unmodified, the characteristics of their remote ancestors of Carboniferous age. Their general growth and external appearance were briefly described in our Introduction,[1] but the probable course of the evolution of the Gymnosperms cannot be sketched without more particular reference to the details of their internal structure.

The Cycadaceæ are allied to true or acicular-leaved Coniferæ mainly through their reproductive organs, whilst in many other respects they are far less developed. Their relative inferiority is especially apparent when the internal structure of their stems is contrasted, for these correspond in plan with such primitive types as *Poroxylon* and *Cordaïtes*, and differ remarkably from the truly exogenous stems of the higher Gymnosperms. A fully matured stem of *Cycas* is composed firstly of central pith; secondly, a single cylinder or zone of primary wood without exterior rings of growth; thirdly, one or more regions of liberian parenchyma and an equal number of woody cylinders; fourthly, the cortical parenchyma; and fifthly, the hypoderma or zone of increase.[2] The permanent bases of the petioles contribute to the latter and make an external covering of considerable thickness. Both the woody zones are traversed by medullary rays, but the second is engendered later than the first, and has a different origin. The fibrous elements of the woody zones are marked with rows of obliquely elliptic areolations, differing, according to Saporta and Marion, alike from those of true or cone-bearing Coniferæ and from other "Progymnosperms," but recalling somewhat more the structure of *Ginkgo* and the Taxeæ. The general plan has little in common with that of the Coniferæ or Dicotyledons; but, due allowance being made for the branching habit and presumably more rapid growth, bears a striking analogy with that of *Cordaïtes*.

The leaves of Cycadaceæ are, according to Sachs, of two kinds; the one described as "dry, brown, hairy, sessile, leathery scales, of comparatively small size," the other large and pinnate, that is, provided with distinct segments inserted on the sides of a usually simple support. In the forms both of the scale-leaves, and of the modified leaves which support the sexual organs, Saporta and Marion see reasons to infer that the now pinnate foliage-leaves must have been originally simple or merely fimbriated along the margins,

[1] *Ante*, p. 14.

[2] See Carruthers' "Memoir on Cycadean Stems," 'Trans. Linn. Soc.,' vol. xxvi, p. 675.

then incised and segmented, and lastly pinnate; in which cases they would have once presented a remarkable affinity with certain abnormal *Cordaïtes* and *Salisburieæ*. The analogy is increased by the presence, common to all these, of a peculiar cellular tissue, called "*tissu lacunaire,*" in the middle of the substance of the leaf and uniting the veins.

The flowers of the Cycadaceæ are always diœcious, the plants being either male or female. They are placed at the summit of the stem, and in all the genera except *Cycas*, they externally resemble fir-cones. The female flower of *Cycas* is composed of a whorl of metamorphosed foliage-leaves, several of the lower pinnæ of which support ovules. These attain a considerable size even before fertilisation, and the fertilised seed "acquires the dimensions and the appearance of a moderate-sized ripe apple, hanging quite naked on the carpel."[1] The stem continues to grow through the whorl of modified leaves forming the female flower, developing first a whorl of scale-leaves and then new whorls of foliage-leaves. Saporta and Marion point out that this is the utmost simplification of which phanerogamous plants are capable, and indicates very clearly the stages through which their evolution from Cryptogams must have progressed. The male flower is composed of numerous smaller undivided staminal leaves, expanded from a narrow base and crowded on the under side with pollen-sacs. In other Cycads the staminal or carpellary leaves are disposed on a shorter and relatively slender stem, and become often hard or lignified. The pollen-cells or microsporangia are grouped in clusters of three or five on the under side of the staminal leaves, like the sori on Ferns. They open longitudinally, and, according to Sachs, "are in all respects much more like the sporangia of Ferns than the pollen-sacs of other Phanerogams, from which they also differ in the firmness and hardness of their wall."[2] The relative size of the grains, their often elliptical form and median furrows are, on the other hand, special to Cycads. The grains are at first formed of only one cell, but subsequently this divides into two cells, the larger of which becomes fashioned into the pollen-tube whilst the smaller again subdivides, so that a Cycadean pollen grain is normally three-celled; a character helping to assimilate the *Cycads* with ordinary Gymnosperms. The carpellary leaves are crowded in a spiral arrangement on the axis of the female flower, except as just described in *Cycas*, each one bearing two ovules on the under surface of the peltate or expanded lamina. Saporta and Marion regard it as probable that they were originally more numerous, covering the surface of the limb, and that the reduction in number is an advance in their evolution. In *Cordaïtes* the fruiting organ is a shoot with greatly modified leaves, the main axis bearing only sterile bracts, from the axils of which the staminal or carpellary leaves are developed, while the bracts serve as involucres. In *Ginkgo* the male flower consists of an axis with staminal leaves bearing pollen-sacs at their summits, much as in *Cordaïtes*; but in the female flower there is no axis, and it consists only of isolated carpellary leaves springing from the axils of foliage leaves, and bearing two, or rarely three, ovules at its extremity.

[1] Sachs, p. 503, English Edition, 1882. [2] L. c., p. 504.

Supposed Cycadaceæ occur in the Upper Carboniferous,[1] and in the Permian several genera are distinguishable. In the Rhætic series representatives of *Cycas* were already differentiated from the rest, or Zamieæ, but even when most numerous and diversified the limits within which they varied were very circumscribed. Their oldest known ancestor is *Noeggerathia foliosa*, of the Middle Carboniferous; and although the leaves even in this are pinnate, those destined to bear the organs of reproduction are little metamorphosed and but slightly smaller than the foliage-leaves. The ovules also were smaller and far more numerous than at present, and for these reasons *Noeggerathia* is justly regarded by Saporta and Marion as a primitive type of Cycad in process of evolution. *Pterophyllum* and *Nilssonia* succeeded it, and already in the Secondary Period the numerous genera did not (with the exception of *Bennettites*) differ in any essential points of structure, so far as is known, from the species living in the present day. They become increasingly rare

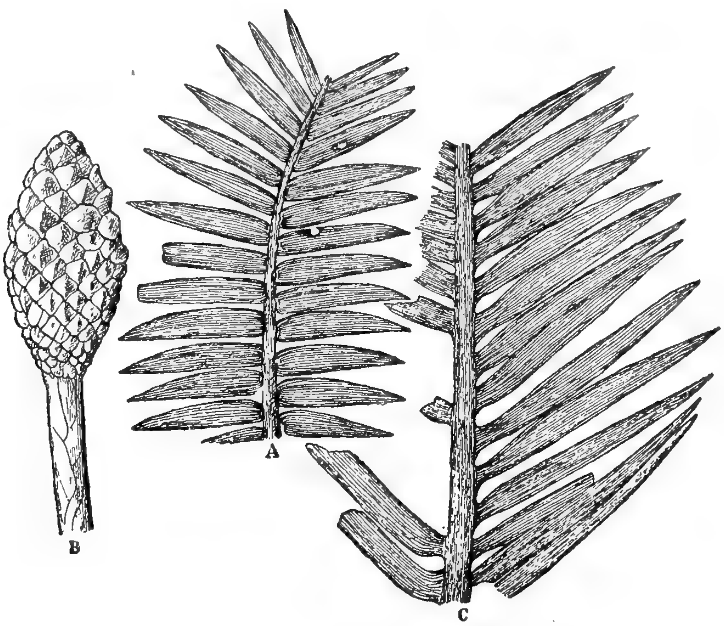

FIG. 39.—The last "European" Cycads. A. *Zamites epibius*, Sap., from the Oligocene of Bonnieux (Vaucluse); a frond of small size. B. *Zamiostrobus Saportanus*, Schimp., female cone from the Oligocene of Armissan (Aude). C. *Encephalartos Gorceixianus*, Sap., middle part of a frond from the Miocene of Kumi (Eubœa), two thirds natural size.—After Saporta and Marion.

as Cretaceous times are passed, and appear to have completely died out in Europe with the Tertiary Period, evidently declining under the competition of newer forms and only surviving in specially favorable stations.

In arriving at the "true Gymnospermic" stage of Saporta and Marion we definitely leave behind all those genera of ambiguous and prototypic character which we have hitherto had under consideration. In these we have traced step by step how the purely

[1] *Pterophyllum Grand'Euryanum*, Sap. and Mar., a plant discovered by M. Grand'Eury, is regarded by Saporta and Marion as a primitive Cycad. 'Evolution des Phanérogames,' vol. i, p. 109, fig. 58.

sexual generation has gradually been suppressed as an independent existence. The spore and the prothallium have become one, and the sexual stage reduced to a few cells, representing the prothallium, developed in the embryo-sac in the seed and in contact with the rudiments of a female prothallium. The pollen grains of Gymnosperms, are according to Sachs, homologous with the microspores of *Selaginella*, since they are subdivided internally into cells representing a very rudimentary male prothallium. The largest of the cells ruptures and becomes transformed into the pollen-tube. The pollen-sacs containing the grains of pollen are produced on the inner sides of staminal leaves, either in pairs or in larger groups, and open at maturity to set free their contents. The macrosporangia are each reduced to a single macrospore called a nucellus or ovule, and may be formed either of the metamorphosed end of the floral axis; or be axillary; or proceed from the carpels. The carpels never cohere so as to form a true ovary before fertilisation, hence the term Gymnosperm; although on ripening they often increase in size so considerably that they close together and conceal the seeds. Cases are, however, " not rare in which the seeds remain quite naked from first to last."[1] One or more embryo-sacs are formed near the apex of the ovule or seed. An endosperm or mass of cellular tissue corresponding to the prothallium of Cryptogams is formed in the embryo-sac, and within this arise Archegonia or Corpuscula. The pollen-tubes penetrate the ovule and reach the corpuscle, impregnating the germinal cell within, called the oosphere, in which the embryo of the future plant subsequently appears. "During the development of the embryo the endosperm (prothallium) becomes filled with nutrient materials and increases greatly in size; the embryo-sac which encloses it grows at the same time, and finally entirely absorbs the surrounding tissue of the nucellus (ovule); the integument, or an inner layer of it, becomes developed into a hard shell, while frequently (in naked seeds) its outer mass of tissues becomes fleshy and pulpy and gives the seed the appearance of a drupaceous fruit (*e.g.* *Cycas*, *Salisburia*). The effect of fertilisation extends to the fertile leaves, which enlarge, swell, harden, and approach each other, and constitute a complex organ, the fruit forming fleshy or woody coatings to the seeds (*e.g.* Juniper), or woody supports beneath them as in Coniferæ."[2] The reproductive organs of the Gymnosperms are thus seen to be very complex. They are simplified in the still higher Angiosperms by the final obliteration of the Archegonia or Corpuscula and of the endosperm or prothallium contained in the embryo-sac, whilst the pollen grains or microspores become almost unicellular, and thereby lose the last trace of the inclosed male prothallium of the Lycopodiaceæ. The seed develops gradually as it ripens, its function being to protect the embryo and to store up nutriment for its use when germinating. The embryo lies in the endosperm which fills the seed and is differentiated distinctly into stem, root, and leaves.

The "true Gymnospermæ," comprehending the order Coniferæ only, have a branching stem, usually arranged in verticels round a central axis. Interiorly the stems are truly

[1] Sachs, p. 498.
[2] Sachs, p. 499.

exogenous, composed of a woody interior and of a bark, these being most distinctly separated from each other by the reproductive cambium layer, which produces annually a new layer of wood on the one side, and of bark on the other. As in the Cycads, the true vessels are confined to the periphery of the greatly reduced central pith. The fibrous wood is arranged in concentric zones without any mixture of intercalated bark, and is uniformly composed of punctated fibres, radially disposed and traversed by medullary rays. The wood is destitute of true vessels and only contains an insignificant proportion of woody parenchyma, except in a few Conifers of relatively rapid growth. The great advance is the permanence of the cambium layer and the consequent regular increase of

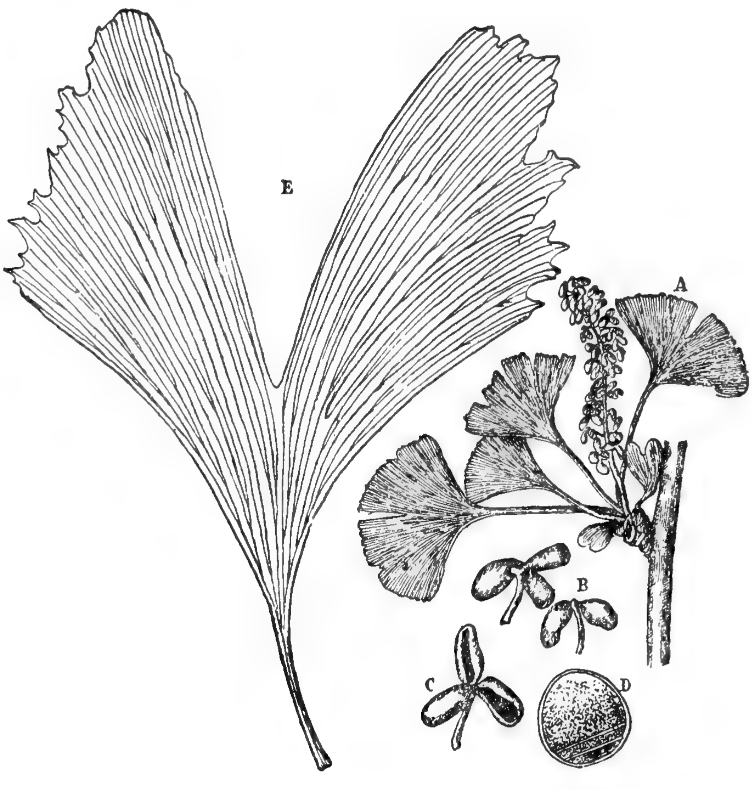

FIG. 40.—Leaves and male organs of *Ginkgo*. A. Lateral branch and male catkin, on the point of emitting the pollen, surrounded by young undeveloped leaves. At the base are two bilobed bracts. B and C. Detached flowers. D. Pollen grain greatly magnified, showing a three-celled interior, surrounded by extine. E. Leaf, two thirds natural size, of the wedge-shaped and deeply-cleft variety. —After Saporta and Marion.

the stem, a growth exclusively confined to the Coniferæ and to Dicotyledons, and the complete separation of the bark from the wood. The bark is composed of three elements, the fibrous inner bark or liber, the parenchymatous second layer, and the outer or suberous bark covered by the epidermis. The leaves are always simple, generally narrow, and most often seated on more or less decurrent cushions, provided with longitudinal veins, solitary or several parallel, simple or forked, but never anastomosing or even joined

by intercalated veinlets. The *Ginkgo* presents in many respects a simpler organisation than the rest of the Coniferæ, and its study is therefore likely to bring us nearer to the starting-point of the Order than that of any other genus.

Ginkgo is the largest-leaved of the Coniferæ. The leaf is fan-shaped on a long and slender petiole, and the fan is generally more or less cleft in the centre and sometimes still further subdivided. There are two fibro-vascular bundles in the petiole from which fine dichotomosing veins proceed. Filling in between the veins there is beneath the epidermis a "lacunary" tissue formed of elongated cells, arranged in transverse bands which anastomose together. The same construction prevails in *Cycads*, and a not dissimilar one

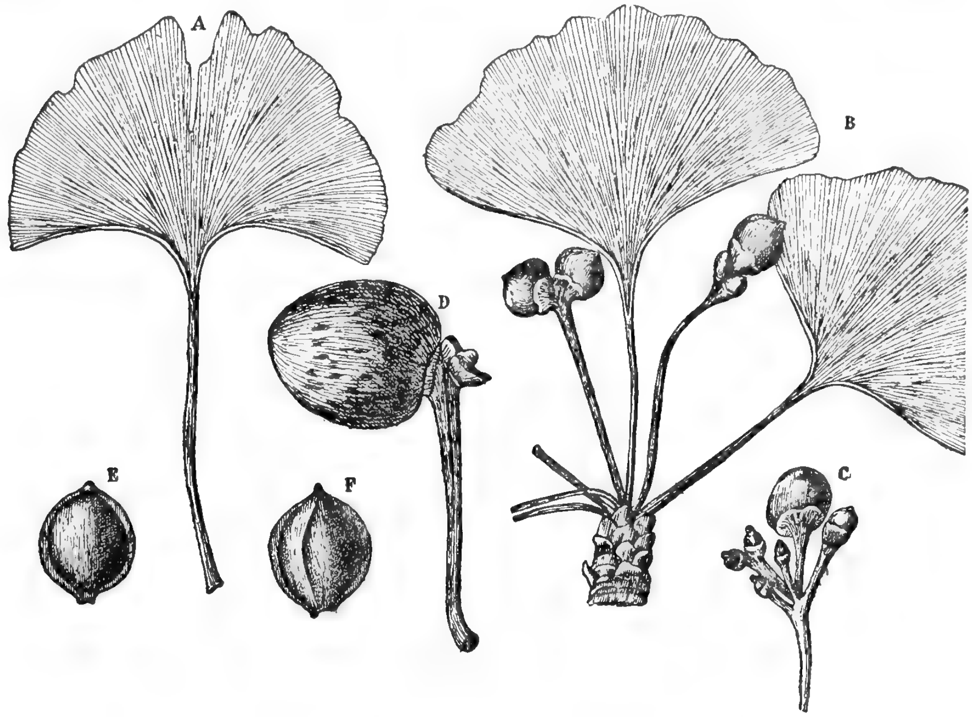

FIG. 41.—Leaves and female organs of *Ginkgo*. A. Bilobed leaf of ordinary type. B. Short lateral and flower-bearing branch, surmounted by a rosette of entire leaves and stems supporting recently fertilised ovules. C. Stem bearing a cluster of ovules on pedicels, only one of which is destined to be developed. D. Stalk bearing two ripe seeds, of which one has been removed to show the scar of attachment. E and F. A bicarinated and a trigonal seed with their fleshy envelopes removed. Half the natural size. After Saporta and Marion.

in *Cordaïtes*. The sexual organs are disposed on abbreviated lateral shoots. The male flower-spike is in form of a catkin, and axillary, each of the altered leaves of which it is composed bearing two or three terminal pollen-sacs at their ends, which depend from short peduncles, as in other *Taxeæ* and in *Cordaïtes*. The female apparatus is placed amidst a rosette of normal leaves, and consists of a group of petioles, supporting each two ovules instead of a bilobed leaf. The matured seed is more like, in structure, that of *Cycas* and of *Cordaïtes*, already described, than that of any other Conifer. Under a fleshy integument there is a hard testa in form of a bi- or tri-carinated nut, the large

kernel of which contains a bulky embryo, furnished with two unequal cotyledons. The stem has a relatively large pith, and by this, as well as by its punctated woody fibre and septiferous bark and some other characters, its relation to Cycads is apparent. The Ginkgos can be traced back to the Carboniferous through a series of increasingly modified forms, even those from the Permian being not dissimilar in aspect to those which still exist. Prof. Williamson is convinced that *Dadoxylon* was a closer ally of *Ginkgo* than of the Cycads, the leaf-bundles being in pairs, a peculiarity of construction now wholly confined to the former. The type was by no means isolated in the Carboniferous as at present, for many varieties of *Dadoxylon,* and fruits resembling those of *Ginkgo* are known, and its ancestral form *Ginkgophyllum* approaches both *Noeggerathia* and *Cordaïtes,* as well as the most ancient Cycadaceæ. The course of evolution does not demand that all Coniferæ should have descended from *Ginkgo* as a common ancestor, but the living species is certainly the only one which, apart from its exogenous trunk, can convey to us a faithful, if weakened, image of the Coniferæ as they existed in times anterior to the organic changes which transformed some into cone-bearers and others into Taxeæ.

It only remains now to trace as far as possible the evolution of the CONIFERÆ from the primitive type. The oldest examples known to us possessed an exogenous growth. Their leaves were broad and attenuated at the base with parallel dichotomising venation. The male and female inflorescence were separated, and formed spikes composed of bracts or metamorphosed leaves arranged round a central axis. The subsequent modifications have been in the direction of the successive reduction of the breadth of the leaf and number of veins, and their combination into a mid-rib; and it is amongst the most primordial genera, *Araucaria* and *Agathis,* that the largest leaves are to be found.

The TAXEÆ are older as a group than the true Coniferæ. During the progressive development of the Coniferæ to their present state, great numbers of types must have been evolved which have since entirely disappeared. A few, more persistent than others, have come down to us and seem to reveal at least some of the stages by which the cone-bearing Coniferæ were differentiated from the rest. There has been a tendency in the Taxeæ for the floral axis to diminish, and in the other orders for it to increase. One well-nigh constant element in the Taxeæ and the Podocarpeæ is the swelling of the substance surrounding the base of the ovule until it forms either a membranous or fleshy cup. *Dacrydium, Podocarpus, Phyllocladus,* and *Taxus* are diverse examples of this. *Saxegothea* is perhaps the highest form of Taxad, for the bracts form a sort of cone, each scale of which bears an inverse ovule at its base, seated in a membranous cup. In the Yew the male flower is made up of a number of bracts, very like the inflorescence of *Equisetum,* as pointed out by Sachs; while the female flowers "spring from the axils of foliage-leaves belonging to elongated woody shoots and have the form of short branches covered with decussate scale-like bracts," the axis of the shoots ending in a terminal ovule.[1] The last is not dissimilar, according to Saporta and Marion, to that of the Abie-

[1] Sachs, p. 515.

tineæ, but the ovule in *Taxus* subsequently develops solitarily on its cup-like base, whilst the support in the Abietineæ takes a scale-like form. A primordial member of the Abietineæ, before the ovules were collected in a cone, should not differ fundamentally in its fruity organs from a primitive Taxad, before its floral axis had been impoverished. While, as already stated, it appears certain that the Taxeæ as a group preceded the true Coniferæ, it is probable that what are now alike cone-bearing Coniferæ were differentiated before the fruiting organs of some of them definitely took the form now common to all. The cone is a branch wholly or partially modified to serve as a support to the female organs, and to protect the seeds after fertilisation until they ripen. In the cones of Cycads the metamorphosed leaves directly support the ovules; but in Coniferæ these organs are situated on structures arising out of the axils of the bracts, which latter do not increase while the ovule-bearing structures are enlarging and producing the ovules. In the Abietineæ an entire branch is modified to form the cone, but in the Cupressineæ only the upper part is transformed. The occasional perfoliate cones of *Cryptomeria* and *Cunninghamia* demonstrate that the middle of the branch was the part originally modified, and that the sterile termination has since been lost through atrophy. In many of the older Coniferæ of the Trias and Rhætic the scales of the cones are more scattered and their leaves less completely altered, producing the long cylindrical forms which so often characterise primitive types such as *Voltzia*, *Schizolepis*, *Glyptolepis*, and *Lepidostrobus*. The most ancient Conifers of which we have definite knowledge, although there must have been still older types, are the *Walchiæ*, a considerable tribe of trees of large growth, clothed with deciduous foliage not differing greatly in appearance from that of *Araucaria Cookii* and *A. excelsa*. The cones, however, were small, ovate or oblong, with lanceolate scales formed of only slightly modified and closely imbricated bracteal leaves firmly attached to the axis. The seeds were small, slightly alate, and free, from one to three being born under each scale. In construction the cone is not unlike that of *Araucaria*, except that the latter possesses but one seed to each scale, and the bases are not persistent to the axis. The *Walchiæ* are associated in the Carboniferous with two genera of *Ginkgos*, *Ginkgophyllum* and *Trichopitys*, together with the last of the *Cordaïtes*. They are succeeded in the later Permian by *Ullmannia* which links them to the Jurassic *Brachyphyllum*. *Voltzia* of the later Permian and Trias is seen, by the disposition of its seeds, and in other respects, to be allied to the Taxodieæ, though its thin imbricated scales, forming a loose and rather large cone, link it also with the Araucarieæ. The Triassic *Albertia* bears a striking resemblance to *Agathis* in its cones, but in foliage it more resembles *Araucaria Bidwillii* and *A. Cunninghami*. *Glyptolepis*, a genus bearing cones with a long axis and small fimbriated scales, carries on the Voltzian type through the Upper Trias.

The commencement of the Jurassic period marks an epoch in the development of the Coniferæ, their characters for the first time approaching sufficiently to those now existing to enable the whole to be placed in living families. At the same time many of the archaic genera, such as *Walchia* and the Sequoia-like *Palissya*, do not survive beyond it, but make

way for the newer and more vigorous types which are ushered in with the first dawn of the Cretaceous period. Jurassic forests appear to have been composed mainly of genera belonging to the Araucarieæ and the Cupressineæ, with an undergrowth of Cycads and of various species of *Brachyphyllum* and Ferns.

Of the five tribes into which existing Coniferæ are grouped the TAXEÆ, through *Ginkgo*, are decidedly the most venerable for their antiquity. The pedigree of this tree is so remarkable and is traceable through such ages, embracing as it does widely divergent forms separated into many genera, that Saporta strongly urges that the extinct ancestral and the living form should be elevated to the rank of a distinct tribe in classifying Coniferæ.

It is somewhat remarkable that while some of the Jurassic species of *Ginkgo* are almost indistinguishable from the living, they seem to have reverted during the Cretaceous and Wealden towards older forms, the leaves of at least one being laciniated or cut up into narrow segments. The Carboniferous *Ginkgophyllum* died out with the Permian, where it is associated with *Trichopitys*. The latter with *Baieria* persisted down to the close of the Secondary period. No other genus is known in the Lias, but in the Jurassic many species, some true Ginkgos, are met with ranging from Australia to within the Arctic Circle. The tribe had greatly diminished in the Cretaceous period though *Baieria* and *Sclerophyllina* were among the survivals. Its later history will be found at p. 46 of this memoir.

The rest of the Palæozoic Coniferæ cannot be placed with certainty in any one of the existing tribes. Their characters seem to unite the Araucarieæ, the Cupressineæ, and the Taxodieæ, and there can be no doubt that the remote period in which they flourished was antecedent to the differentiation of these tribes from each other. It has been proposed by Saporta to unite them in a single tribe, that of the WALCHIEÆ of Schimper, and the advantages of this arrangement, at least as a provisional one, are obvious. The principal genera would be *Walchia*, *Ullmannia*, and *Brachyphyllum*. The latter was an immense genus, with very thick, closely inlaid, or imbricated leaves, and small cones, either persistent or caducous, composed of persistent scales which were also closely imbricated, and, not greatly differing, except that they were more lanceolate, from the foliar leaves. None of the Walchieæ so far as is yet known survived the Jurassic. *Brachyphyllum* is the last of the Coniferæ which cannot properly be classed in an existing tribe,[1] and in leaving it we seem to quit the unknown.

The ARAUCARIEÆ are of an antiquity which is only surpassed among Conifers by *Ginkgo*, though the Carboniferous woods, for a long time thought to be Araucarian, are now placed in the widely removed progymnospermous genus *Cordaïtes*. Undoubted Araucarian forms first appear in the Trias, but with ambiguous characters, which render it probable that they may be ancestors of all three existing genera. Mr. Carruthers was the first to demonstrate beyond all doubt that true *Araucariæ* existed in the Inferior Oolite of

[1] It is placed with the Taxodieæ by Schimper.

England; and their presence in contemporaneous beds has since been ascertained in France. The British species are *Araucarites sphærocarpus*, Carr., *A. Phillipsii*, Carr., and *A. Brodiei*, Carr., from the Inferior Oolite, and *A. Pippingfordensis* from the Wealden.[1] Two of the Jurassic species seem to have shed their scales similarly to the existing trees; but in the first the cone is unbroken and the scales are seen to have been woody and persistent like those of *Araucaria Bidwilli*, though otherwise resembling *A. excelsa*. The Greensands of France have yielded important foliage of undoubted *Araucariæ*, as well as cones, some of the latter as large as any now existing.

The Taxodieæ form another tribe of remarkable antiquity. The oldest form which can be placed with certainty in it is *Voltzia*, a genus which appears in the second half of the Permian. Two other genera, *Cheirolepis* and *Schizolepis*, occur in the Rhætic and Lias and are principally known from their small, elongated, and bracteated cones. The singular Rhætic *Palissya* is more completely known, the cones being frequently attached to the foliage, which is dimorphic, while the cone is composed of pointed and laterally lobed scales and pointed bracts. *Sphenolepis* is another fine Rhætic genus with terminal cones clustered together, which survived to the Cretaceous. The genus *Swedenborgia*, so far limited to the Rhætic of Sweden, and *Echinostrobus* of Solenhofen approach more nearly to the existing genera *Cryptomeria* and *Athrotaxis*. The Taxodieæ thus abounded in the Trias, and attained their maximum towards the close of that formation and in the Lower Lias, when they seem to have preponderated over all other plants showing a preference for humid stations. Thenceforward they declined and in the later Jurassics the Cupressineæ had already to some extent replaced them. *Sequoia*,[2] however, abounded in the Cretaceous period, especially within the Polar Circle, and a *Taxodium* also appeared before its close.

One of the most remarkable characteristics of this tribe, according to Saporta, is the tendency to polymorphism in the foliage of every genus belonging to it, not only with regard to different species of the same genus, but also in individual plants. This was especially apparent in the more ancient representatives of the family, and led the earlier authors to assign to different species foliage of *Voltzia* and *Palissya* which might have grown on the same tree, so extreme is the range in the size and form of the leaves. In describing the Eocene Taxodieæ during the progress of the present work, I have repeatedly called attention to the polymorphism which is apparent in many of them, a peculiarity still manifest in nearly every living species.

The entire tribe is certainly a declining one at present. The few genera comprised in it are represented by single or few species, and seem all decreasing and retreating relatively to the positions they formerly occupied, while none have maintained themselves in Europe.

The Cupressineæ seem to have been first definitely ushered in with the Jurassic

[1] 'Geol. Mag.,' vol. iii, p. 249; and vol. vi, p. 3.

[2] Probably the oldest species is described by Carruthers from the Gault of Folkestone, as *Sequoiites Gardneri*, 'Geol. Mag.,' vol. vi, p. 7.

period, and do not assume any important position until the Oolites are reached. A fragment of foliage with squamiform leaves, imbricated in four rows, appears to have been brought from the Carboniferous of Melville Island, but no other foliage bearing any resemblance to that of a Cupressineous plant has elsewhere been found in rocks inferior to the Upper Trias or Lias. In the older Jurassics the branches when met with are small and scattered, but in the Middle and Upper Oolites they are large, numerous, and of many types, though fruits are unfortunately always rare. Along with *Widdringtonites, Palæocyparis, Thuyites, Phyllostrobus,* none differing much externally from living forms, we come across the still existing genus *Widdringtonia.*

The Cupressineæ are believed by Saporta and Marion to be an offshoot from the same stock as the Taxodieæ, with the elements of the cone, diminished in number and more perfectly soldered and combined together, arranged on a decussate or verticillate plan. In the oldest known species of the existing genus, *Widdringtonia,* the leaves are imperfectly arranged in pairs, and the four scales of which the cones are composed are thought to be metamorphosed from them. The leaves of the Cupressineæ, at first irregularly disposed, as shown in Jurassic species, finally became in most of the genera regularly arranged in pairs, the lateral being compressed and keeled, and the front and back flattened. The highest degree of complexity is presented by the most recent type, the Junipers, in which the fleshy scales are soldered together so as to convert the cone into an edible berry. There is thus evidence of progressive development in the tribe which is now, next to the Abietineæ, the most extensive among Coniferæ.

The ABIETINEÆ are regarded as an ancient tribe, with characters fixed in very remote times, which varied within small limits, and for a long time increased but very slowly in importance. They seem to have descended from an ancestry different from that of the two preceding tribes, whose common origin is apparent in many ways, and which were perhaps originally an offshoot from the stock which produced the Taxeæ. Saporta has long upheld the view that their cradle was in the extreme north of the hemisphere to which they are practically confined even now.

The researches of Dr. Nathorst have set the first appearance of the tribe as far back as the Rhætic of Scania. They reappear in the Inferior Oolite of Spitzbergen, where several genera seem to be present, and have been met with in Norway, Sweden, Siberia, and Spitzbergen, while they are all but unknown in the Jurassics to the south.[1] In Cretaceous times, however, they had spread farther south, and in the Neocomian, Gault, and Chalk of Belgium, the north of France, Normandy, and England, many curious species occur combining characters which are now distinctive of different genera and subgenera. Thus, the *Cembra, Tæda,* and *Pinaster* sections of *Pinus* were imperfectly separated; cones like those of Cedar were formed of persistent scales, but were themselves caducous, instead of possessing a persistent axis with scales which fall off as at present; and the

[1] A small cone with thin scales, from the Kimmeridge Clay, is described as *Pinites depressus* by Carruthers, 'Geol. Mag.,' vol. vi, p. 2.

characteristics of *Abies, Tsuga, Picea, Cedrus,* and *Larix* seem to blend and lose themselves in these ancestral species.[1] The types which were formerly the most widely spread now extend farthest to the south.

The structural characters of the cone are especially important in this tribe. The support of the ovule represents an axillary shoot reduced to a single phyllode, supporting two ovules, and is only slightly and superficially soldered to the bract. After fertilisation this support alone increases in size and forms the scale of the cone, while the bract dies away or presents no appearance different to an ordinary leaf. The ovules are always inverse and buried in the substance of the scale, usually becoming surrounded with a membranous wing formed from its outer cellular layer. The general appearance and later history of the tribe have already been described (p. 60) in this Memoir.

With the Cretaceous, or rather with that indefinite age which intervened between the close of the Cretaceous and the dawn of the Eocene, unrepresented by any stratified rocks in England, we close the book on the evolution of Gymnosperms, for nearly all the archaic anomalous genera which held the place of our Larches, Pines and Spruces, Cypresses, and Junipers, give way to living genera and even species.

[1] The following simple classification of the Abietineæ proposed by Saporta seems specially applicable to the needs of the geologist.

Tribes.	*Genera.*	*Sub-genera.*	
PINEÆ.	PINUS	*Strobus.*	Leaves fasciculated by fives; apophyses terminal; scales of cone persistent.
		Cembra.	Leaves fasciculated by fives; apophyses terminal; scales of cone caducous.
		Pseudo-strobus.	Leaves fasciculated by fives; apophyses central; scales of cone persistent.
		Tæda.	Leaves fasciculated by threes; apophyses central; scales of cone usually caducous.
		Pinaster.	Leaves fasciculated in twos; apophyses central; scales of cone persistent or caducous.
LARICEÆ	PSEUDO-LARIX		Leaves caducous; cone pendent; scales loosely imbricated, detaching themselves from the axis on maturity.
	LARIX		Leaves caducous; cone erect, with scales persistent.
	CEDRUS		Leaves perennial; cones with scales detaching themselves from the axis at maturity.
SAPINEÆ	ABIES. Leaves inserted direct, and leaving a discoidal cicatrice	*Abies vera.*	Cones erect; scales detaching from the axis at maturity; bracts more or less visible, persistent at the base of the scales.
		Tsuga.	Cones small, terminal, pendent; scales few and persistent; leaves relatively broad and short, regularly distichous.
		Pseudo-tsuga.	Cones terminal, with persistent scales; leaves very linear and irregularly distichous.
	PICEA		Leaves inserted on elevated cushions and decurrent.

The Break Between the Cretaceous and Eocene Rocks in the British Area.

It is a remarkable fact that the extermination of so much that was pre-existing of both the marine and terrestrial Fauna, embracing nearly all the shelled Cephalopods and all the gigantic Saurians which had till then occupied the foremost place, should have been accompanied by a similar wholesale disappearance among Plants. To suppose that this period was an exceptionally fatal one, annihilating entire orders of the animal kingdom, is to admit, in the complete absence of evidence, a break or jerk in the majestic progress of life upon the earth; and this is repugnant to common sense. It is more consonant with our present views to suppose that we are in presence of one of those vast gaps in the geological record which we know must have occurred over and over again in every upheaved area upon which sedimentary rocks had been deposited. In turning from the last Cretaceous deposit in Europe, we seem, so far as the Plant world is concerned, to finally break with the past, while the first deposit of the Eocene appears like turning over the first page of the history of things as we see them now. It is thus, perhaps, worth while to turn aside for a moment to take stock, as it were, of the closing events of the Cretaceous, so far as we know them at present, in order to estimate the true nature of the apparently sudden bound in the usually stately and measured march of evolution.

It appears that during the Chalk formation a great wave of depression passed across Europe, travelling from the west to the east, permitting the ingress of the Atlantic, and forming a gulf over what is now Central Europe, which constantly increased in magnitude. We need not believe that this gulf was formed by any sudden catastrophe, for there is no reason to doubt that the sea conquered the land by the same methods and at somewhere about the same rate that it encroaches now, and that therefore its advance over many thousands of square miles of *terra firma* would be an exceedingly lengthened process. We cannot gauge the time this occupied; but we know that since the appearance of Man Southampton Water has been formed, and a tract between Alum Bay and Studland, some fifteen miles long and five or six miles broad, has been swept into the sea, and several species, like the Mammoth, have become extinct. The rate of the encroachment depends mainly on that of the subsidence and the original height of the land, but what has here been effected in a subsiding area serves to show roughly how vast a time must have been needed for the chalk sea to have crept from Kent to the Crimea, and to have covered the enormous area of Europe over which its traces still remain. As the land subsided and became sea, blue and green muds were thrown down, to be succeeded in due course by the deeper deposits of chalky ooze. It would be physically impossible for the Chalk, supposing

it to represent Globigerina-ooze,[1] to have been directly deposited on a former land surface, and we consequently find that it is invariably preceded by some more littoral sediment. The nearer the original centre of depression or focus of subsidence, the older the Greensands and Gaults must necessarily be; and the farther we recede from it in any landward direction, the newer they will be. Now, apart from physical evidence, a comparison of the Faunas of our Chalk with those of any European bed correlated with it to the eastward would at once show that if one were older than another, it would be that of our area. Forms like *Mosasaurus*, which only appear in our very latest Chalk deposits, abound in Cretaceous deposits of more central Europe; whilst others, such as *Ichthyosaurus*, found abundantly in our Chalk-marl are, on the contrary, absent in them. The rapid increase in the proportion of long-canaled and other Eocene-looking Gastropods in the Chalk, as we recede from Kent and Sussex, reaches a maximum in the Danish Upper Chalk, and indicates most conclusively a more and more recent period of deposition for the beds in which they occur. The littoral and each subsequent zone must in fact have been constantly travelling outward and forward, accumulating only until

[1] True Chalk is a pure white limestone, composed of the remains of Foraminifera, valves of Ostracoda, excessively minute Coccolliths, shell prisms of Inocerami, Sponge spicules, and other débris of organic life. It was, until recently, admitted to be a truly oceanic deposit, of similar nature to Globigerina-ooze; but Mr. Wallace, supported by the late Dr. Gwyn Jeffreys, has put forward the view that it was formed in shallow water ('Island Life.') Its vast extent, homogeneous nature, and freedom from terrestrial impurity, show that it must have been formed remote from land, while its larger organisms, mainly Echinoderms and Sponges, are, with some exceptions, such as are now met with in abyssal depths. Mr. Wallace laid some stress on the difference in composition of fresh Globigerina-ooze and Chalk, as shown by analysis; but Mr. Murray has recently stated that the percentage of carbonate of lime varies from 40 to 95 in the ooze. The comparison took no account of the fact that the Chalk had been elevated for ages, during which it has acted as a sponge for the collection and percolation of rainwater charged with carbonic acid, which has been ceaselessly removing some of its original constituents. Its silica has been dissolved and re-precipitated as flint, its iron has been segregated into crystalline masses, its manganese into dendritic markings, siliceous sponge skeletons have been dissolved and replaced by calcite, calcite shells by silica, and aragonite shells removed entirely. Layers of Chalk a foot in thickness have been reduced to an inch by the removal of lime in solution. The late Dr. Gwyn Jeffreys had not studied the question, and based his conclusions upon the Mollusca only, and these chiefly of the Chalk-marl, and he seemed unaware that only the calcite shells remained in true Chalk. Of these shells *Terebratula*, *Pecten*, *Lima*, and *Spondylus* are the chief genera still existing, and all but the last are already known to inhabit water 1400 fathoms in depth. Moreover, if the Chalk sea did not communicate with the Arctic Ocean, as Prof. Prestwich and others believe, and was shut off from the Antarctic by land between Africa and South America, as there is also much evidence to support, its abyssal depths would have been warm instead of icy cold, and its former abyssal inhabitants, accustomed to warmth, would have sought shallower water in order to find an equal temperature, and become, as Gwyn Jeffreys states them to be, a tropical assemblage at the present day. The blue and green muds of the 'Challenger' pass into Globigerina-ooze with an increased depth, and their equivalents of Gault and Greensand pass into Chalk in exactly the same way. The alternative theory of Wallace, that Chalk is decomposed coral mud, could not have been advanced by a geologist, as while it contains some well-preserved solitary corals, not a trace of a reef-building coral has ever been met with either in or surrounding it, nor even in any contemporaneous deposit.

the ever-increasing depth led to a change in the sediment. Thus, though beds of Greensand or Chalk may be perfectly continuous, with precisely the same lithological characters, it is absurd to assert that portions of either when separated widely apart by degrees of latitude and longitude must be synchronous. So far from this, the Chalk-with-flints of one locality must most certainly have been deposited synchronously with the Chalk-without-flints of another, and this in turn with the Chloritic marl of another, and the Greensand of another. The shallower-water zones, such as the Greensand, would travel forward so long as the sea continued to encroach, and along the farthest confines of the gulf would recede again when elevation set in, without any Chalk having been deposited over them, so that some "Upper Greensands" might be newer than any Chalk. It is probable that each minor zone was a zone of depth, characterised by the same quality of sediment, and a Fauna to some extent peculiar to it, which kept up with it as it travelled farther and farther landwards. There might thus be great similarity (homotaxis) in the Fauna of each zone at long intervals of distance, and its distinct characteristics maintained over the most extensive areas, without, for all that, its contents having lived synchronously over the whole area.

We have noticed that the Neocomian and Gault of England and Western France contain a varied and considerable Flora, represented mainly by foliage and fruits of *Coniferæ,* without affording the slightest trace of the presence of angiospermous Dicotyledons. Even the Grey Chalk and the Blackdown Beds have only yielded Conifers and a *Williamsonia* of Jurassic type. We cannot account for their absence by supposing our area to have been isolated, for in the preceding Wealden period neither its Fauna nor Flora differed from that of Europe. But when we reach Aix-la-Chapelle, we find the Chalk and Greensand resting upon beds containing a Flora largely made up of Dicotyledons, and still farther off, in the Cenomanian[1] of Bohemia, living genera such as *Magnolia,* and farther on still, equally developed Dicotyledons in the slightly newer Turonian. Such facts were hitherto completely inexplicable, but it now appears probable that the interval required for the Chalk to progress even only 300 or 400 miles, may have endured long enough to permit an enormous progress in the evolution of phanerogams. Nor does the 1200 or 1400 feet of vertical Chalk remaining in our area, at all represent the completed formation; for, as the prolonged subsidence finally ceased and gave place to an equally slow elevation, all the lessening zones of depth must have travelled back with the receding ocean, and left a series of beds arranged inversely to that preserved to us. The planing action of the sea has removed all this newer series, just as it has planed away an older mass of the width of the English Channel; and it is still slowly but inexorably cutting down to its own level all the cliffs that form its shore-lines. The Eocene seas, from beginning to end, were ceaselessly engaged in this work, and their enormous deposits of flint shingle mark how much had fallen a prey to them. Nor have the Cretaceous rocks enjoyed any respite from the work of

[1] Equivalent of Grey Chalk and Chalk-marl.

destruction down to the present day, so that what remains is a mere fragment of what once existed.

It was during the interval that elapsed between the formation of the newest Chalk now left in England and the oldest Eocene, that Dicotyledons were introduced, if not actually evolutionised, and our existing Flora practically came into existence. All the Upper-Cretaceous Floras of Europe also flourished during this interval, but we cannot say, with our imperfect record, exactly the order in which they came in, and must be content to regard them, in a general way, as far newer than they appear to be stratigraphically. Much of the American Cretaceous series should, perhaps, also be placed somewhere in this interval, though many well qualified to judge regard it as dating from an older period. Without this digression we could not have formed so adequate an idea of the completeness of the break between the Eocene and the Cretaceous period, nor realised that the so-called Cenomanian and Turonian Floras of Europe may belong to epochs completely different from those represented by the same horizons in Kent and Sussex.

The break in the continuity of the history of the Coniferæ here introduced corresponds to that which actually occurs in nature in our area. It is not to be understood that this is the only gap in their history, for there are many, but there are none of such present importance (or that perhaps are less adequately realised), for it immediately precedes that chapter in their development with which we are most immediately concerned, and it is absolutely necessary, therefore, that its magnitude and duration should be recognised, in order to appreciate the meaning of the great change in the character of the Flora, which we find to have taken place in the interval.

We have already seen that several very anomalous genera of Coniferæ occur in company with Dicotyledons wherever Floras of late Cretaceous age are met with. The Aix-la-Chapelle Flora was very rich in these, and contains many new to science, which may now be open to study. The curious genera *Inolepis, Cyparissideum,* and *Sphenolepidium* were mentioned at page 17 of this Memoir. *Cunninghamites,* a genus differing considerably from *Cunninghamia,* characterises the Cretaceous of Saxony and Bohemia. *Geinitzia* is another genus which has been found abundantly at Quedlinberg, also in the environs of Dresden, and near Neustadt in Austria. Its cones are cylindrical and elongated, formed of scales at right angles to the axis, with peltate or hexagonal heads marked with deep and converging grooves, and sheltering three or four wingless seeds at their base, while the foliage is dimorphic, being closely imbricated as well as looser like that of *Cryptomeria.* Nor must we forget that many of the supposed Cretaceous *Sequoiæ* are very imperfectly known, and may prove when examined, to be as anomalous as those of Aix-la-Chapelle already mentioned. It thus appears that a large proportion of even the latest of the Cretaceous Coniferæ belonged to types which have since become extinct.

It is quite otherwise when we reach the Eocene. The British Eocene Coniferæ bear,

with just sufficient exceptions to prove the rule, a remarkable resemblance to still existing species. In some cases the fossil and the living plants are, so far as their organisation can be compared, unquestionably the same species, though, even in these cases, they do not bear the specific names attaching to the corresponding recent plants. However well preserved, some of the organs necessary for accurate botanical determination are certain not to be in the perfect state requisite for proper examination, and we have therefore to rely greatly on superficial resemblances. It seems to be the opinion of botanists that they should not, under such circumstances, be definitely united together. For all practical purposes, however, their identity might, in some cases, be as safely admitted as that of a vertebrate animal from its skeleton, or a mollusc from its shell.

If among them there are few strange and extinct types to marvel at, we must at least become lost in wonder at the extraordinary plant migrations they disclose, and the great changes in the relative positions of land and water, and of climate necessary for such migrations to have been practicable. The time is not yet when we can discuss profitably what these changes must have been, but at a future time we may be in a position to do so. We shall only show that during the vast lapse of time known as the Eocene, what are at present the shores of Great Britain supplied a common home for genera and species of Coniferæ which now only inhabit the remotest parts of the earth.

Of Cupressineæ, now only represented in England by the Juniper, we formerly possessed in our Southern Counties two Frenelas identical with species now exclusively confined to Australia and Tasmania, and a *Libocedrus*, which does not differ from the magnificent Incense-cedar of the Sierra Nevada. These give place in the Middle Eocene to a Cypress resembling the Funeral-cypress of China, while in the Irish area the lovely *Cupressus torulosa* of the Himalayas flourished in the greatest profusion.

There is now no representative of the fast-diminishing Taxodieæ living in Europe, nor within 5000 miles of Great Britain, but then every genus was represented within its area, for we not only had the *Glyptostrobus* of China, but the great Deciduous or Swamp Cypress of Florida. Both types of *Sequoia* seem to have formed part of our Eocene Flora, although some of our Eocene foliage is merely placed in the same genus with the Californian Red-wood, on account of the resemblance it bears to a French *Sequoia*. We had, however, two undoubted and beautiful species of the genus *Athrotaxis*, never previously found fossil, and now exclusively confined to the far-off Island of Van Diemen's Land, nearly 12,000 miles away. Further and repeated examination has confirmed the opinion that the Sheppey form is practically indistinguishable from *Athrotaxis selaginoides*, while the exquisitely preserved Hordwell specimens are identical with *Athrotaxis cupressoides*. While these were flourishing in England, the well-known *Cryptomeria* of Japan was thoroughly established in Ireland and Scotland.

The determinations of some of the Taxeæ are less satisfactory, for though *Ginkgo*, which abounded in Scotland, can always be identified, the Yew, though evidently of great

antiquity and probably present in many fossil Floras, has often been overlooked in consequence of its easily detached and insignificant fruits.

Of the PODOCARPEÆ we have, perhaps, several representatives belonging to more than one section of *Podocarpus*. The genus is a large one, and now almost confined to the Southern Hemisphere, and no species inhabits any country nearer to us than Tropical Africa. The species are still imperfectly known and resemble each other very considerably. The fossils cannot, therefore, in most cases, be absolutely assigned to existing species.

Two of our most graceful forms belong to the interesting tribe of ARAUCARIEÆ, supposed by many botanists to have been extinct in European latitudes since the Jurassic period. One of these is indistinguishable from *Araucaria Cunninghami*, the Moreton-Bay Pine, now limited to a somewhat restricted area in Northern Australia, and the other is the remarkable extinct *Doliostrobus*, uniting foliage something like that of the species just mentioned, and utterly unlike that of any living *Agathis*, with fruit that can only be placed with the latter genus.

Nothing new has come to light regarding the British Eocene species of the extensive Tribe ABIETINEÆ. The closed cones of two, if not three extinct species, have been found in the littoral sands of the Thanet Beds, and another in the estuarine mud of the London Clay. They formed no part of the inland Flora of the Middle Eocene so far as the vegetable débris deposited in the fresh-water clays of the Lower and Middle Bagshot Beds reveal. Not a vestige of them has ever been met with, not a solitary needle or scale among the myriads of fruits and seeds and leaves that our Bagshot series has yielded. But directly marine deposits are once more reached, as in the Bracklesham and Barton Beds, they again appear, and in great variety,[1] just as if they were fruits of the sea and formed an integral part of marine Faunas instead of a terrestrial Flora. It would almost appear that the Pine cones found stranded in the silts of our Middle Eocene seas had been drifted there from long distances and other lands. It is a mere conjecture, for they may equally have been brought down from the hills and uplands of the interior; but they certainly formed no part of the rich and varied forests whose falling leaves and fruits were floated and embedded at Bournemouth near to where they fell. They are equally absent in all the Upper-Eocene and Oligocene fresh-water beds, from Hordwell to Hempstead, and rich as many of these are in plant remains, Pine cones only reappear in one brackish-water mud bed of the Bembridge Marl.

In the Irish and Scotch Basalts, of Lower Eocene age, they occur in only one deposit of plants, out of many. But where they are present, at Ballypalady, they abound beyond every other plant; their bark, branches, and seeds, their needles, solitary and in clusters, and their cones open and closed, prove to how large an extent the neighbouring forests must have been composed of Pine trees. Except for a chain of accidental circumstances,

[1] A collection made during 1885 has shown that there are species at Highcliff distinct from those of the Bracklesham Beds.

—first that a basalt dyke had saved them from being denuded away; secondly, a railway was planned across them to avoid a gradient that would not now present any difficulty; thirdly, that they stood high enough above the general level to necessitate a cutting, the Ballypalady Flora would have remained unknown. Its preservation happily shows us that the remains of such gregarious and local trees as Pines and Firs may find their way in great abundance into the river-muds at one place, without betraying any trace of their presence in other not far distant muds, deposited apparently under the same conditions. But for accident we might have drawn a conclusion relative to the North-British Eocene similar to that we have just considered regarding the Eocene of our Southern Counties, but which would have been utterly erroneous. So unsafe must inferences ever be in this study when founded on negative evidence.

With regard to the leading species, *Pinus plutonis*, Baily, of Ballypalady, further research has shown a considerable resemblance between its cones and those of *P. Quenstedti*, Heer, of the Cretaceous Quadersandstein of Moletein,[1] the only difference being in the somewhat larger size of the latter, though the associated needles are thought to be in bundles of five. Other species as old resemble it, and its cylindrical form may be takenas a possible indication of conidserable antiquity.

FIG. 42.—Monstrous cone of *Abies Veitchii*, with bracts reverting into foliage leaves, and the axis prolonged into a branchlet with ordinary leaves. ('Veitch's Manual.')

None of the other genera of the Abietineæ are well represented, but a number of fragments are placed together in the genus *Tsuga*, simply because the more perfect cones resemble those belonging to living species of that genus more than any other. Sir Joseph Hooker has kindly reminded me that the generic characters upon which *Tsuga* is separated from *Abies* are not, and could not well be, apparent in the fossils. The determination is based on general likeness, and on such characters as are visible, and is not a strictly scientific one, nor one to which importance need be attached. The Pines, Firs, Larches, and Cedars belong to the most recently developed tribe of Conifers, and so far, none of their species had, even in the Eocene, assumed the precise forms met with at the present day.

[1] [Heer, "Beiträge zur Kreide-Flora," 1, 'Neue Denkschr. der Schweiz. Gesell.,' 1869.]

TABLE OF BRITISH EOCENE CONIFERÆ, WITH THEIR NEAREST EXISTING ALLIES, ARRANGED ACCORDING TO BENTHAM AND HOOKER'S CLASSIFICATION.

ORDER. CONIFERÆ.	Lower Eocene of Scotland.	Lower Eocene of Ireland.	English Eocene below the London Clay.	London Clay.	Lower Bagshot.	Middle and Upper Bagshot.	Upper Eocene and Oligocene.	Range of nearest existing representative.[1]
TRIBE I. CUPRESSINEÆ.								
Genus—*Callitris.*								
C. curta, *Bowerbank*, sp.	...	...	...	—	...	...	...	C. Australis and C. robusta, Australia.
C. Ettingshauseni, *Gardner*	...	...	...	—	...	...	...	C. Endlicheri, Australia.
Genus—*Libocedrus.*								
L. adpressa, *Gardner*	...	...	—	...	...	...	...	L. decurrens, California.
Genus—*Cupressus.*								
C. taxiformis, *Unger*, sp.	...	...	...	...	...	—	...	C. funebris, China-Japan.
C. Pritchardi, *Goepp.*, sp.	...	—	...	...	...	...	...	C. torulosa, Himalaya.
TRIBE II. TAXODIEÆ.								
Genus—*Taxodium.*								
T. europæum, *Brongt.*, sp.	...	...	—	...	...	—	...	T. heterophyllum, China-Japan.
T. eocænum, *Gardner*	...	...	...	...	...	—	...	T. distichum, Florida variety.
Genus—*Sequoia.*								
S. Tournalii, *Brongt.*, sp.	...	...	...	...	...	—	...	S. sempervirens?, California.
S. Shrubsolei, *Gardner*	..	...	...	—	...	...	...	S. gigantea, California.
Genus—*Athrotaxis.*								
A. subulata, *Gardner*	...	...	...	—	...	...	...	A. selaginoides, Tasmania.
A. Couttsiæ, *Heer*, sp.	...	...	...	...	...	—	—	A. cupressoides, Tasmania.
Genus—*Cryptomeria.*								
C. Sternbergii, *Goeppert*, sp	—	—	...	...	...	...	...	C. japonica, China-Japan.

[1] Before the range of these British fossil species in other countries can be tabulated a revision of some of the determinations will be necessary. So long as all the Yew-like foliage is included in one species, *Sequoia Langsdorfii*, and all the Cryptomeria-like foliage in another, *S. Sternbergii*, very little progress in this direction can be made.

ORDER. CONIFERÆ.	Lower Eocene of Scotland.	Lower Eocene of Ireland.	English Eocene below the London Clay.	London Clay.	Lower Bagshot.	Middle and Upper Bagshot.	Upper Eocene and Oligocene.	Range of nearest existing representative.
TRIBE III. TAXEÆ.								
Genus—*Ginkgo*.								
G.? eocænica, *Ett. & Gard.*	...	...	...	—	...	...	...	G. biloba, China-Japan.
G. adiantoides, *Unger*	—	...	...	...	...	...	...	G. biloba, China-Japan.
Genus—*Taxus*.								
T. Campbelli, *Forbes*, sp.	—	...	...	...	...	...	...	T. adpressa, China-Japan.
T. Swanstoni, *Gardner*	...	—	...	...	...	...	...	T. cuspidata, China-Japan.
TRIBE IV. PODOCARPEÆ.								
Genus—*Podocarpus*.								
P. eocænica, *Unger*	...	...	...	...	?	—	?	? P. andina, Chili.
P. Campbelli, *Gardner*	—	?						? P. falcata, Cape.
P. elegans, *Gardner*	...	...	...	...	—			Extinct.
P. argillæ-Londinensis, *Gardner*	...	...	...	—	...	...	...	P. elata, Australia.
P. incerta, *Gardner*	...	...	...	...	...	—	...	Extinct.
TRIBE V. ARAUCARIEÆ.								
Genus—*Araucaria*.								
A. Goepperti, *Sternb.*, sp.	...	...	...	...	...	—	...	A. Cunninghami, Australia.
Genus—*Doliostrobus* (extinct).								
D. Sternbergii, *Goepp.*, sp.	...	...	...	...	...	...	—	Extinct.
TRIBE VI. ABIETINEÆ.								
Genus—*Pinus*.								
P. macrocephalus, *Lindley and Hutton*, sp.	...	...	—	...	...	...	...	Extinct.
P. ovata, *id.*	...	...	—	...	...	...	...	Extinct.
P. Prestwichii, *Gardner*	...	...	—	...	...	...	...	? P. monticola, California.
P. Dixoni, *Bowerbank*, sp.	...	...	...	...	...	—	—	? P. laricio, Mediterranean.
P. Bowerbankii, *Carruthers*, sp.	...	...	...	—	...	—	...	?
P. Plutonis, *Baily*	...	—	...	...	...	...	...	? P. sinensis, China-Japan.
P. Bailyi, *Gardner*	...	—	...	...	...	...	...	Extinct.
Genus—*Tsuga*.								
T. Heeri	...	—	...	...	...	...	...	? T. Pattoniana, California.

If we examine this table, and contrast the Coniferæ of England in it with those of Scotland and Ireland, we discover indications of considerable differences in temperature. The varieties of *Callitris*, *Cupressus*, *Taxodium*, and *Araucaria* are such as are to be found growing in company near the water's edge in Madeira, whilst the more northern assemblage would be found there in grounds a couple of thousand feet above the sea. Farther north, in the Greenlandic Eocene, the North-British *Cupressus*, *Podocarpus*, and *Cryptomeria* give way in turn to a still more temperate assemblage, comprising the Red-wood, Deciduous Cypress, and probably Juniper, *Thuja*, *Cephalotaxus*, and Fir, while the Yew, Pines, and Ginkgo maintain their ground. There is thus little reason to believe that the climate of the Northern Hemisphere, though very much hotter during a part of the Tertiaries than at present, was then more uniform than now. An extensive migration of species, consequent on a considerable rise and fall of temperature, has caused the same plants in some cases to become embedded in very different latitudes, but it needs no argument to prove that all these widely separated deposits need not necessarily be of exactly the same age, and there is fortunately ample evidence in support of this. Not a single species of Conifer from either Ireland or Scotland, with the exception of Ginkgo, which first appears in southern Europe in the latest Miocene or possibly the Pliocene, has ever been met with in any beds of known Miocene age, and to maintain longer that the great Basaltic formation is in its entirety of the latter age, is simply to ignore the accumulated evidence.

The close connection of the Eocene Flora of the English basin with the present Australian Flora is another of the most obvious of the facts to be gathered from this table. The two species of *Frenela* (*Callitris*) and the *Athrotaxides*, known by their fruits, are purely Australian types, while the *Araucaria* and some of the Podocarps, though less perfectly known, are no less characteristically Australian. All these elements completely disappear from the Scotch and Irish Eocene basin, the plants of which seem mainly related to those of Eastern Asia. The essential difference between the Floras of our northern and southern basins, apart from the respective temperatures required by them, appears to lie in the fact that, whilst the former were almost restricted to types now indigenous to Eastern Asia, the latter possessed, in addition to these, types now peculiar to Australia and America.

In order to complete the Monograph as far as possible, the following Tables of Reference are appended, showing all the Coniferæ from British rocks of early Tertiary age recorded previous to the commencement of this work, and the position now assigned to them :

Names as published.	Status in this Monograph.
Cupressinites globosus, Bow.	Believed not to be Coniferous.
,, *elongatus*, Bow.	
,, *recurvatus*, Bow.	
,, *subfusiformis*, Bow.	

Names as published.	Status in this Monograph.
Cupressinites curtus, Bow.	United as *Callitris curta*.
,, *Comptonii*, Bow.	
,, *crassus*, Bow.	
,, *thujoides*, Bow.	
,, *subangulatus*, Bow.	
,, *corrugatus*, Bow.	Believed not to be Coniferous.
,, *sulcatus*, Bow.	
,, *semiplotus*, Bow.	
,, *tesselatus*, Bow.	
Cupressites taxiformis, Ung.	*Cupressus taxiformis.*
Sequoia Couttsiæ, Heer.	*Athrotaxis Couttsiæ.*
Sequoia Hardtii, Heer.	*Sequoia Tournalii.*
Taxites Campbelli, Forbes.	*Taxus Campbelli.*
Cupressites elegans, De la Harpe.	*Podocarpus elegans.*
Pinites macrocephalus, Lindl. & Hutton.	*Pinus macrocephala.*
Pinites ovatus, id.	*P. ovata.*
P. Bowerbankii, Carr.	*P. Bowerbankii.*
P. Dixoni, Bow.	*P. Dixoni.*
Pinus Plutonis, Baily.	*P. Plutonis.*
Cupressites MacHenrii, Baily.	*Cupressus Pritchardi.*
Sequoia Du Noyeri, Baily.	*Cryptomeria Sternbergii.*

Ettingshausen, in the list of Sheppey fossils published in the 'Proceedings of the Royal Society,' and already referred to, admits the following:

Callitris curta, Bow.	*C. recurvatus*, Bow.
C. Comptonii, Bow.	*C. subfusiformis*, Bow.
Solenostrobus subangulatus, Bow.	*C. globosus*, Bow.
S. corrugatus, Bow.	*Hybotha crassa*, Bow.
S. sulcatus, Bow.	*Sequoia Bowerbankii*, E. & G.
S. semiplotus, Bow.	*Pinus Sheppeyensis*, E. & G.
Cupressinites elongatus, Bow.	*Salisburia eocænica*, E. & G.

The only species which I am able to admit, of the entire number, are the first and the last on the list, but I add a new *Callitris, Podocarpus, Athrotaxis,* and *Sequoia.* Similarly in the list of the Alum Bay Flora the following occur:

Glyptostrobus europæus, Brong.	*Sequoia Langsdorfii*, Brong.
Callitris curta, Bow.	*Sequoia Couttsiæ*, Heer.
Cupressinites globosus, Bow.	*Podocarpus eocænica*, Ung.

I am thoroughly acquainted with the specimens on which the above are based, and I do not think they afford satisfactory grounds for supposing these *Coniferæ* to occur at Alum Bay. The beds there are singularly poor in *Coniferæ*, and all the known specimens of true Conifers belong to a single polymorphic species, which the attached fruit shows to be *Podocarpus elegans.*

Order.—GNETACEÆ.

The third order of Gymnospermæ, though comprising but three genera, is of the highest possible interest, for it possesses characters which serve in some respects to bridge the immense gap separating the Coniferæ from the angiospermous Dicotyledons. The three genera, *Ephedra, Gnetum, Welwitschia,* differ as much as even the various tribes in the Coniferæ from each other, and it is obvious that there can be no very close relationship between them, though sufficient likeness exists to allow them to be grouped in a single order. Saporta and Marion regard them as so many offshoots which have fallen out at widely different periods on the line of march, and remained stationary,—in other words, whose development has been arrested whilst their companions have progressed towards Angiosperms. At the same time, they believe them to be descended from a common ancestor of the *Taxeæ,* rather than that they are direct links between the existing *Coniferæ* and Angiosperms. Their origin must, in any case, be very remote, notwithstanding that so few traces of them have been discovered. Striated and articulated branches and scales have been described by Heer as *Ephedrites,* from the Jurassic of Siberia, and Saporta refers to analogous remains from the Inferior Oolite of the Côte d'Or. A more important discovery, however, is that of the female organ of an Ephedra-like plant in the Upper Carboniferous of the district of Autun, recently described by Renault in the 'Comptes Rendus' of the French Academy.

All the genera have their organs arranged in pairs, on a decussate plan, each alternate pair being at right angles to the last. Their embryos are dicotyledonous and stems jointed. Their wood has the usual Gymnospermous structure, and is marked with discs resembling especially that of *Phyllocladus,* though approaching in its greater complexity to that of Dicotyledons.

Ephreda seems by far the most primitive of the genera. Its species are all shrubs, without foliage leaves, and with green-jointed and repeatedly branching stems. A pair of opposite, minute, and partly sheathing leaves occur at each node, and the branches as well as the flowers proceed from their axils. The flowers are arranged in diœcious inflorescences, the male in catkins, and the female terminal on axillary stalks.

The former possess an involucre formed by a pair of bracts, partly soldered together, from the middle of which rises a staminal column bearing a number of anthers, or pollen chambers, corresponding to microspores and stamens. The pollen grains are divided across internally, according to Strasburger, by a membrane, as in the *Abietineæ,* only thinner. The female organs are protected by an integument of altered leaves, which form a rudimentary ovary. The ovule corresponds to that of the *Taxeæ,* and the endosperm produces but one archegonium. The fruit is a succulent cone, formed of two carpels, with a single seed in each.

In Gnetum the species are trees or creeping shrubs, with jointed and knotty branches and opposite entire leaves, which are not distinguishable from those of Dicotyledons. The flowers are monœcious, produced on cylindrical, stalked, and jointed catkins, and spring from the axils of the leaves. These catkins bear verticillate leaves, in the axils of which the flowers, both male and female, are agglomerated. The former are composed of a pair of bracts partially soldered together, forming an involucre from the middle of which rises a staminal column, composed of two staminal leaves supporting pollen chambers which correspond to the stamens of Dicotyledons, and are also in part the homologues of microspores. The female flower is fashioned of altered bracts which combine in pairs to form a double or even triple integument or perianth, the inner one being elongated like a style. The ovule is in structure that of a Gymnosperm, but enveloped like an Angiosperm, though the ovary is formed of undeveloped bracts, instead of carpellary leaves. It is solitary and the seed has an outer succulent coat.

Welwitschia is a most singular and abnormal plant, inhabiting the arid regions of South-west Africa, between the 14th and 23rd degrees of south latitude. Only a single pair of leaves, after the cotyledonary leaves, is developed, which eventually become leathery and split into shreds, attaining a length of six feet, and resting on the ground. The intervening woody stock thickens and hardens, assuming an obconical form, tapering rapidly towards the root, but never rising more than a foot above the ground, though the table-like top may spread horizontally several feet in diameter.

The circumference of the stem bears short-jointed branching flower-stalks, six to twelve inches in height, each fork terminating in a small oblong monœcious cone, scarlet when mature, under the decussate scales of which are flowers or seed. The female flowers have naked ovules not essentially differing from those of other Gymnosperms. The male flower is pseudo-hermaphrodite, containing anthers and an ovule, though the latter is always abortive or unfertilised. *Welwitschia*, through its male flowers, thus presents the nearest approach to Angiosperms met with in any Gymnosperm.[1] Only one species is known.

No trace of anything referable to *Gnetum* has been found in our Eocenes, unless the knotted and twisted stems found abundantly at Sheppey belong to it. A fruit from Sheppey, apparently a thin oval shell of the size of a small nutmeg kernel, was labelled "*Gnetum*" by Bowerbank; but it was in fragments when I saw it and cannot be restored. There are at present about fifteen species, confined to the tropics of Asia and America, with two outliers in Africa and Fiji.

The peculiarly-jointed and striated stems of *Ephedra* can, however, be picked out in abundance from the masses of pyritised twigs left by the tide at Sheppey, and there is no doubt that a species similar to that now living on the shores of the Mediterranean forms part of the Sheppey fossil Flora. I have also come across a stone perforated with

[1] See Sir J. D. Hooker in 'Trans. Linn. Soc.,' vol. xxiv; and Sach's 'Text-Book of Botany,' "Gnetaceæ."

twigs possessing all the characters of *Ephedra,* on the shores of Lough Neagh. Species have been described by Unger from Sotzka, by Heer from Switzerland, and by Ettingshausen from Häring.

Some thirty existing species of *Ephedra,* are known. They are erect or scandent, leafless, copiously-branching shrubs, abounding on the sandy seashores of Eastern Europe, North Africa, temperate and subtropical Asia, and extra-tropical America from Chili to California.

CEDAR OF LEBANON.
(Veitch's 'Manual.')

LIST OF EOCENE GENERA AND SPECIES

DESCRIBED IN THIS VOLUME.

Synonyms are in italics.

GENERAL INDEX.

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PLATE XXI.

FROM THE BASALTIC FORMATION, GLENARM.

Cryptomeria Sternbergii, Goepp., sp.

Fig. 1. Foliage with cones attached.
2. Transverse section of a cone.
3. Two cones.
4, 5. Longitudinal sections of two cones.

(Collected by the Author. In the British Museum.)

E C Woodward del et lith.

EOCENE CONIFERÆ.

West Newman & Co. imp.

PLATE XXII.

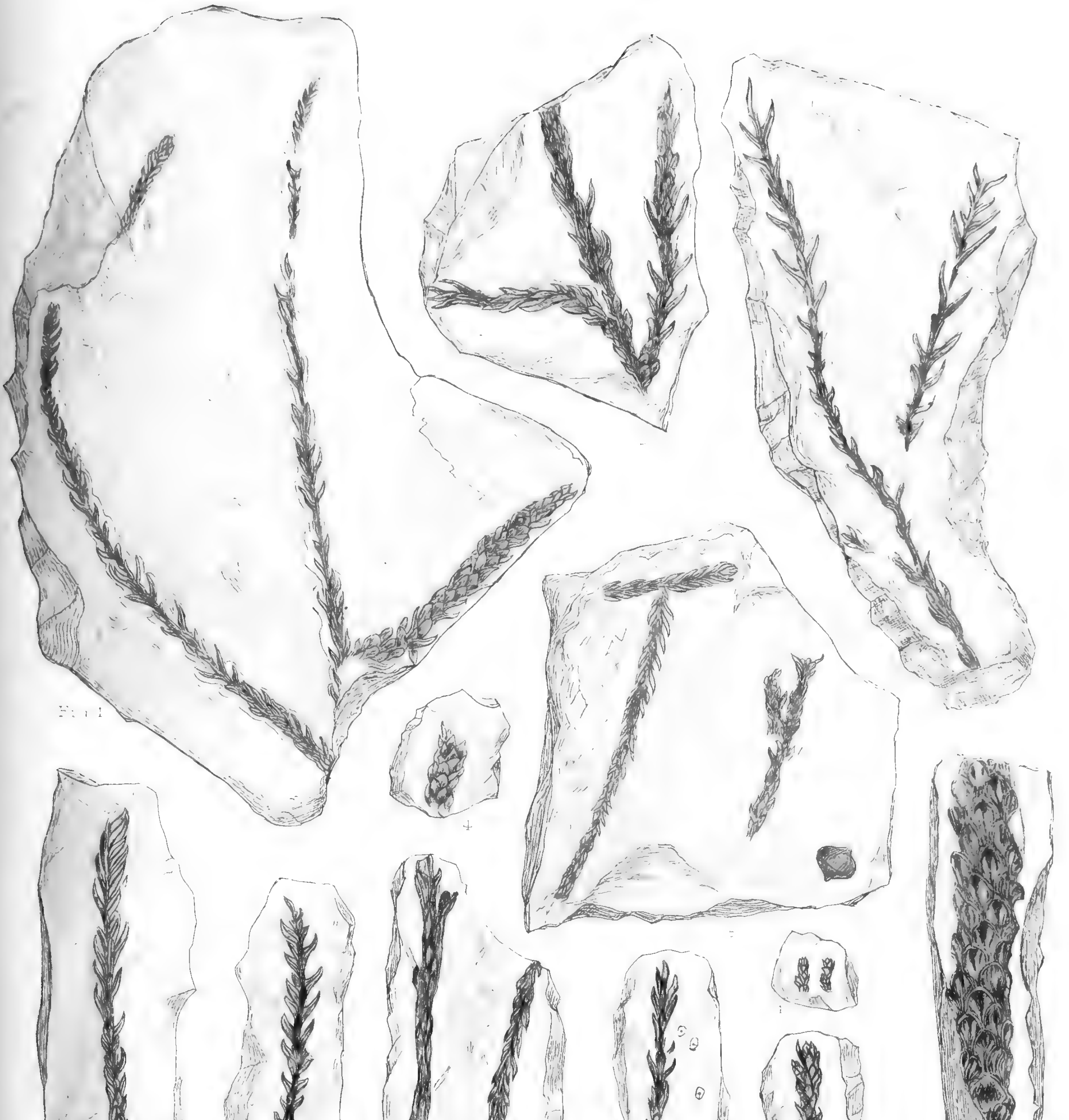
FROM THE BEMBRIDGE MARLS, GURNET BAY.

Doliostrobus Sternbergii, Goepp., sp.

Figs. 1—12, except fig. 10. Various examples of the foliage. The disc on fig. 5 is possibly the scale of a cone of the same species.

10. *Athrotaxis Couttsiæ*, Heer, sp.

(In the Collection of Mr. E. A'Court Smith.)



J. S. G. sculp.

EOCENE CONIFERÆ

PLATE XXIII.

From the Bembridge Marls, Gurnet Bay.

Doliostrobus Sternbergii, Goepp., sp.

Branch and foliage.

(In the Collection of Mr. E. A'Court Smith.)

E.C. Woodward lith. EOCENE CONIFERÆ West, Newman & Co imp.

PLATE XXIV.

From the Reading Beds, Reading.

Taxodium europæum, Brongt.

(Collected by the Author. In the British Museum.)

EOCENE CONIFERÆ

PLATE XXV.

FROM THE BASALTIC FORMATION, ARDTUN HEAD, MULL.

Ginkgo adiantoides, Unger.

Figs. 1, 3. Under side of leaves.
2, 4, 5. Upper side of leaves.

(Collected by the Author. In the British Museum.)

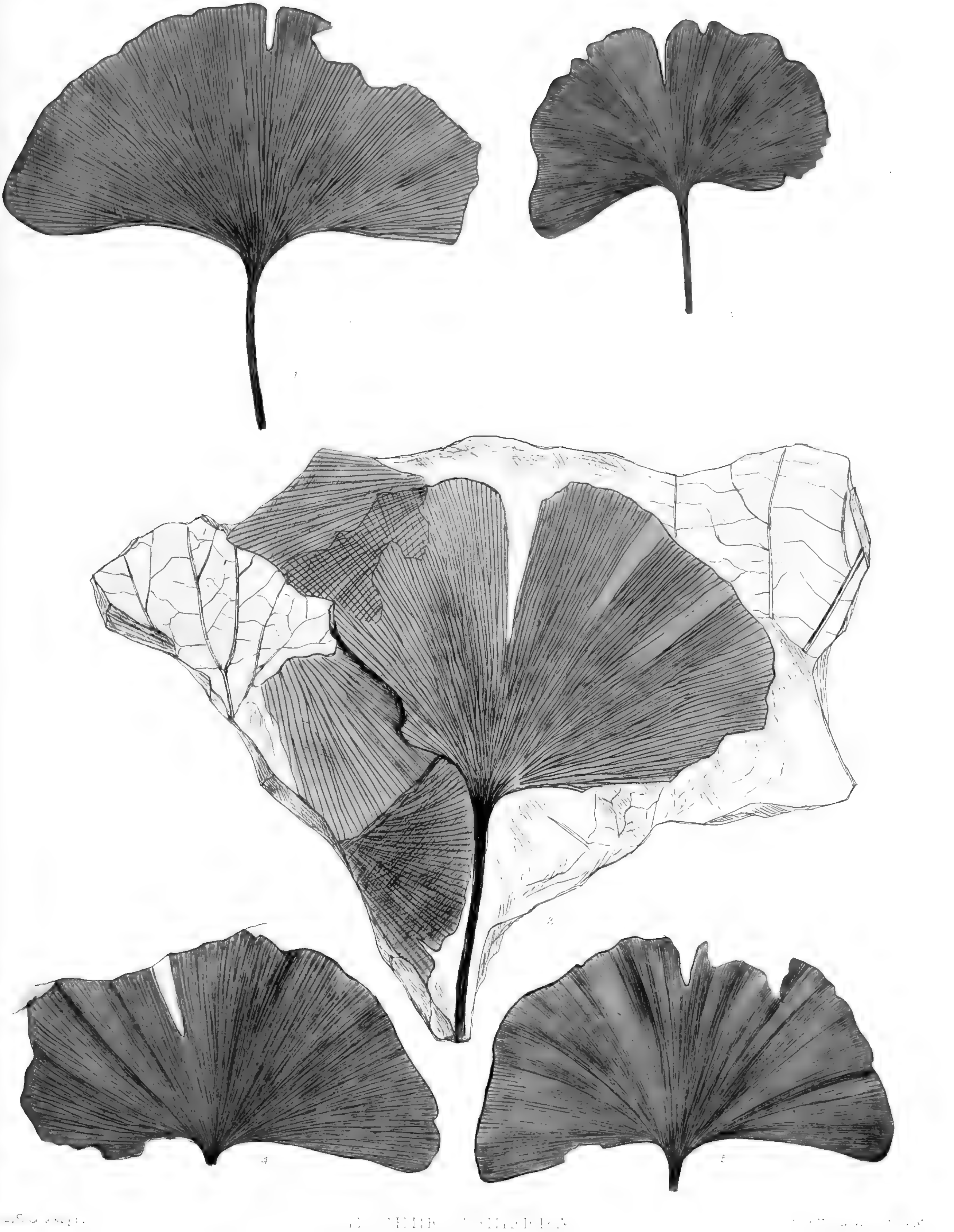


PLATE XXVI.

FROM THE BASALTIC FORMATION, ARDTUN HEAD, MULL.

Podocarpus Campbelli, sp. nov.

Fig. 1. Detached leaflets and a terminal shoot.
2. A branchlet with foliage.
3. A young branchlet.

(Collected by the Author. In the British Museum.)

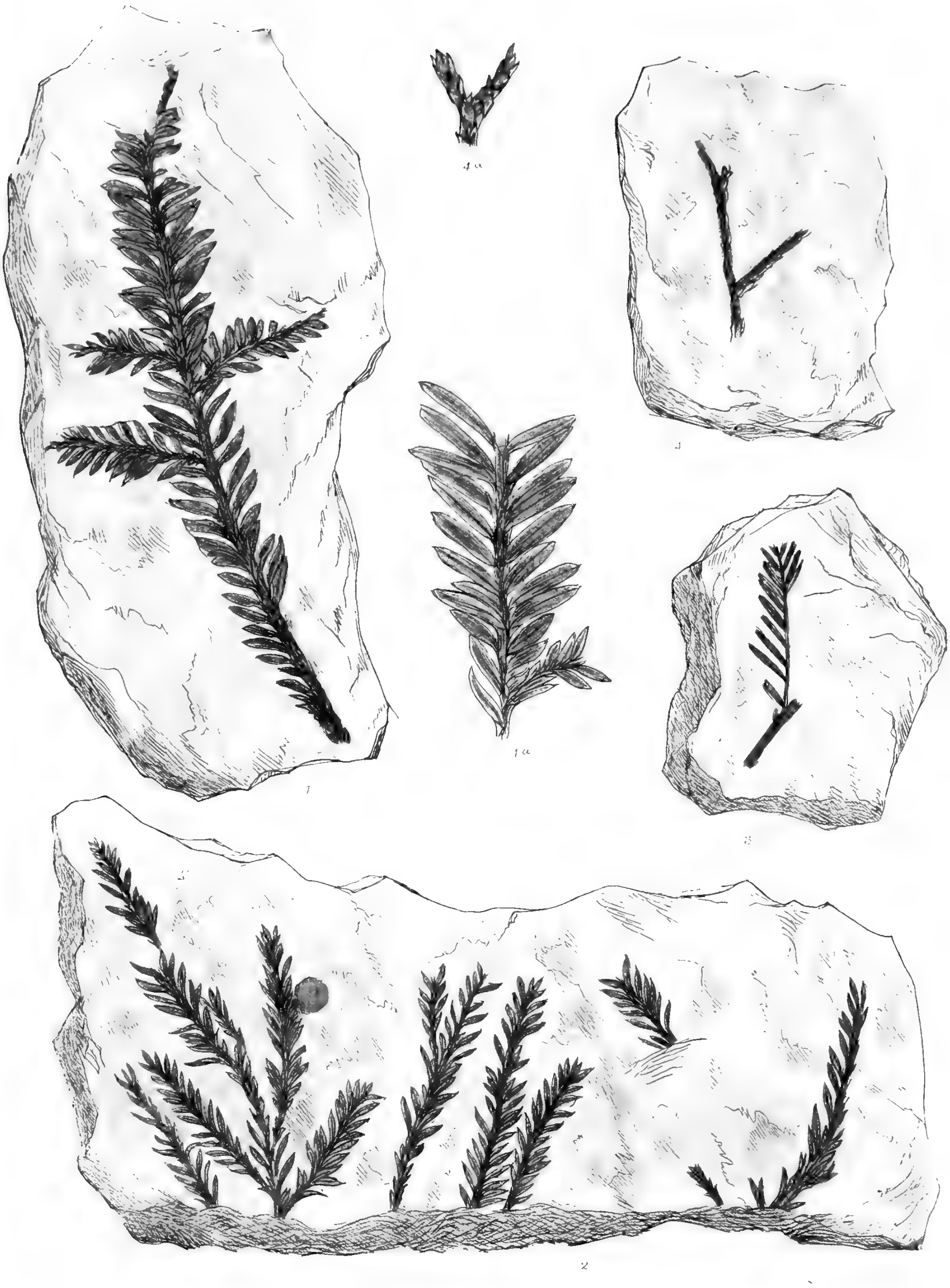
MIOCENE CONIFERÆ

PLATE XXVII.

Figs. 1—3 from the Basaltic Formation, Ardtun Head, Mull.
4 from the Bembridge Marls, Gurnet Bay.

Taxus Campbelli, Forbes, sp.

Fig. 1. Foliage; fig. 1, *a* same enlarged. Collected by the Author.
2. Foliage in the Collection at Inveraray.
3. Foliage of Taxodium (?). Author's collecting.
4. *Athrotaxis Couttsiæ*, Heer, sp. In Mr. A'Court Smith's Collection.
4*a*. Part of same enlarged.



J S G sculpt. EOCENE CONIFERÆ. [illegible] Newman & Co. [illegible]

THE

PALÆONTOGRAPHICAL SOCIETY.

INSTITUTED MDCCCXLVII.

VOLUME FOR 1885.

LONDON:

MDCCCLXXXVI.

A MONOGRAPH

OF THE

BRITISH STROMATOPOROIDS.

BY

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PART I.—GENERAL INTRODUCTION.

Pages i—iii, 1—130. Plates I—XI.

LONDON:

PRINTED FOR THE PALÆONTOGRAPHICAL SOCIETY.

1886.

PRINTED BY
J. E. ADLARD, BARTHOLOMEW CLOSE.

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INTRODUCTORY REMARKS.

It may be doubted if there be any small group of fossil organisms which has given greater trouble to its investigators than that of the Stromatoporoids. Their study is, in fact, attended with quite peculiar and special difficulties, as will become abundantly evident in the course of the following Monograph. For my own part, I am very willing to admit that I have been led, by a prolonged and minute study of a very extensive series of these organisms, to modify or abandon various views which my earlier researches had induced me to accept as more or less probable. Nor, of course, do I claim anything approaching to finality for the present work, though I may be allowed to hope that the results herein set forth may afford a satisfactory basis for further and more extended inquiries.

Much of the difficulty attending the investigation of this group of fossils arises from the fact that so many specimens, though seemingly unaltered, have in reality been so far affected by mineralisation as to exhibit structural features which are only capable of proper interpretation in the light of the facts shown by other comparatively unaltered examples, or which, in the absence of such examples, become positively misleading. It sometimes happens, indeed, that almost all the specimens from some particular region are thus structurally affected by mineralisation, and that their study can only be satisfactorily carried out by means of examples obtained from the corresponding formation of some other region. Thus, I think it may fairly be asserted that the investigation of the Stromatoporoids of the Devonian Limestones of Devonshire, most of which are extensively altered by crystallisation or distorted by pressure, would prove an exceedingly difficult or well-nigh impossible task, except by the aid afforded by comparison with the similar but less altered forms which occur in the Devonian Rocks of Germany. Moreover, in the determination of these, perhaps to a greater extent than is the case with any other group of fossils, progress is absolutely impossible except by an unstinted application of the modern methods of microscopical inquiry—methods which involve considerable labour, and to which all observers are not equally willing or able to have recourse.

For the above-mentioned reasons, amongst others, it has come to pass that the Stromatoporoids have been, to a large extent and until comparatively recently, one

of the *opprobria* of palæontology. It is true that excellent work has been done in reducing this chaotic group to something like order by von Rosen, Roemer, Steinmann, Bargatzky, Carter, and others, but most of this work has been necessarily fragmentary. That, in any case, much yet remains to be done is sufficiently evidenced by the fact that there are hardly any *species* of Stromatoporoids which are at this moment so clearly defined by illustration and description that their claims to specific distinctness would be at once and unhesitatingly admitted by palæontologists. Indeed, there are not wanting those who hold that, in spite of all apparent differences, the great majority of the described types of Stromatoporoids may be perhaps only variations of one or two forms, and therefore not entitled to specific distinction at all.

My own researches have led me to think that when sufficient material is available the distinctions between the different genera and species of the Stromatoporoids are just as well marked and just as readily recognisable as they are in the case of any other group of fossils in which the method of investigation by means of thin sections is likewise absolutely indispensable.

The present Monograph is based mainly upon my own collection of Stromatoporoids, embracing a very large series of examples which I have obtained from the Silurian and Devonian Rocks of Britain, as well as a series from the corresponding formations of North America, and a very extensive series from the Devonian strata of Germany. I have likewise recently visited Esthonia, and have made large collections of Stromatoporoids from the Silurian Rocks of that interesting region. I may also be permitted to add that in carrying out this investigation, as far as it has already gone, I have had occasion to personally prepare considerably over one thousand thin sections of Stromatoporoids, the labour involved in this being one which will be appreciated by all who have engaged in similar work.

Though my own collection has supplied most of the material with which I have worked, I am nevertheless very deeply indebted to many of my fellow-workers for the most cordial aid in the way of specimens or otherwise. I would more particularly express my gratitude to Mr. Champernowne, not only for the most generous assistance in the way of specimens from the Devonian Rocks of Devonshire, but also for much most valuable and suggestive advice. I owe a similar debt of gratitude to my friend, Dr. George J. Hinde. I am also under the greatest obligations to Mr. William Madeley and Mr. J. F. Whiteaves, both of whom have supplied me with material which would have been otherwise inaccessible to me, and the want of which would have rendered this work seriously imperfect. I have likewise received the most ungrudging help from Professor Schlüter, Dr. August Bargatzky—whose recent death will be deplored by all interested in the Stromatoporoids, Professor Ferd. Roemer, Monsieur E. Dupont, Professor J. W. Spencer,

Dr. Fr. Maurer, Mrs. Robert Gray, and Mr. R. Etheridge, junr. To Professor Schlüter, in particular, my best thanks are due for the help which he so freely accorded to me in studying the original types of Goldfuss and Bargatzky, and in collecting Stromatoporoids from the Devonian deposits of Germany. I am, further, deeply indebted to the kindness of my friend, Magister Friedrich Schmidt, who conducted me over the Silurian districts of Esthonia and Oesel, which his own researches have rendered classical ground, and who assisted me in examining in the University of Dorpat the originals of the Stromatoporoids described by Baron von Rosen in his well-known treatise on this group of organisms.

With regard to the general plan of the Monograph, it is sufficient to say that the first portion will be devoted to a general survey of the entire group of the Stromatoporoids, as far as such a survey seems to be at present possible; while the second and concluding portions will deal solely with the descriptions of the British species. I may add that I have made no attempt to deal in any way with any but the Palæozoic forms of the Stromatoporoids. There are certain Mesozoic and Kainozoic fossils which will, in all probability, ultimately find a place in this group, but no sufficient material has been available to me for the investigation of these.

The plates and wood engravings of this, the first instalment of the work, have been drawn from the specimens and slides by myself; and I take this opportunity of expressing my sense of the accuracy and beauty of Mr. Hollick's reproductions of my drawings upon the stone. In preparing the figures illustrative of microscopic structure, I have been in many cases greatly assisted by an excellent series of micro-photographs; and I am much indebted to Mr. George Gellie, of Aberdeen, for the care and intelligence with which these have been executed by him.

A MONOGRAPH

OF THE

BRITISH STROMATOPOROIDS.

I. HISTORICAL INTRODUCTION.

The singular extinct organisms of which the genus *Stromatopora*, Goldfuss, is the central type, and which we may conveniently speak of by the general name of the "Stromatoporoids," constitute a great group of fossil Invertebrates, which are specially characteristic of the Ordovician, Silurian, and Devonian formations, if not absolutely confined to strata belonging to these periods. Possessing a calcareous skeleton, and often attaining to very considerable dimensions, they enter very extensively into the formation of many of the older Palæozoic limestones. Abundant as they are in the Silurian and Devonian deposits of various regions, the investigation of their structure is attended with peculiar difficulties; and it is not therefore surprising to find that the most diverse views have been entertained as to their nature and zoological relationships. The groups to one or other of which they have been most commonly referred are the Sponges, the *Foraminifera*, the Corals, and the *Hydrozoa*. The results, however, of the most recent investigations, render it hardly a matter of doubt that they are truly referable to the *Hydrozoa*, and that they are more or less closely related to the Hydrocorallines on the one hand, and to the *Hydractiniidæ* on the other. The general progress of scientific research as regards the Stromatoporoids will, however, be best gathered from the following brief historical summary:

The genus *Stromatopora* was originally founded by Goldfuss ('Petrefacta Germaniæ,' Bd. i, p. 21, 1826), and was defined by him as including hemispherical Corals, with a calcareous skeleton composed of alternating dense and porous layers. He originally assigned to the genus a place between the Millepores and the Madrepores, but in a later portion of his great work he expressed the opinion that the

genus could not properly be referred to the true Corals. The first species described by Goldfuss under the head of *Stromatopora*—and the species therefore which constitutes the type of the genus—is *S. concentrica*, a name which has obtained universal currency, and which has been employed by palæontologists for a large number of different Stromatoporoids from various parts of the Silurian and Devonian formations. As *S. concentrica* is the type of the genus *Stromatopora*, it becomes a matter of the greatest importance to ascertain precisely its characters and its minute structure, and with this end in view I have made a careful examination of the original specimens of this, and of the other species of Stromatoporoids described by Goldfuss, all of which are preserved in the Museum of the University of Bonn. My friend, Prof. Schlüter, has also had the kindness to have prepared for me thin sections of the original specimen of *S. concentrica*, Goldf., and of some others of the Goldfussian types, such sections not having been previously in existence. It may be as well therefore that I should indicate here the general results that I have arrived at as to the characters and structure of the different forms of the Stromatoporoids which Goldfuss has described and figured in the 'Petrefacta.'

(1) *Stromatopora concentrica*, Goldf.—The type-specimen of this form, as figured by Goldfuss ('Petref. Germ.,' Taf. vi, fig. 5), is preserved in the Bonn Museum, and has the form of a large mass, composed of numerous thick concentric strata, separated by narrow interspaces which are more or less largely filled with oxide of iron. The concentric strata ("latilaminæ") are from $1\frac{1}{2}$ to 3 mm. in thickness, and are more or less undulated. The general texture of the fossil is so dense that no clear idea can be obtained as to the minute structure of the skeleton by the use of a hand-lens. Besides the figured specimen, the Bonn Museum possesses another example of *S. concentrica* of precisely the same general aspect, the two having very probably originally formed part of one fossil.[1] A microscopic examination of thin sections of *S. concentrica*, Goldf., shows that the skeleton is essentially a complex network of anastomosing calcareous fibres, so disposed as to enclose correspondingly complex anastomosing canals. In the main, two sets of fibres may be distinguished, though the two are so united as to form a continuous reticulation. The fibres of one series are vertical, and each of the successive concentric strata ("latilaminæ") of which the skeleton is composed is traversed by such fibres running continuously from the under to the upper surface. The fibres of the other series are tangential to the surface, or at right angles to the vertical fibres, and are very irregular. There are, also, two corresponding series

[1] I may mention that at one locality near Gerolstein, in the Eifel, I have collected a number of specimens which in general characters, and in their mode of preservation, are absolutely undistinguishable from the above-mentioned originals of Goldfuss, and I have little doubt that Goldfuss collected his specimens from the same locality.

of canals. Thus each concentric stratum, or "latilamina," is traversed by irregular vertical canals, which are sometimes crossed by delicate cross-partitions or "tabulæ," and there are also numerous irregular and tortuous horizontal channels by which the vertical tubes are placed in communication with one another.

Though the skeletal elements are thus theoretically divisible into two series, the two are really fused with one another into a continuous reticulation. The general tissue of the skeleton is, therefore, exceedingly similar to that of the recent genus *Millepora*, Lam., the principal difference between the skeleton of *Stromatopora concentrica*, Goldf., and that of *Millepora*, being that the zoöidal tubes of the former are not divisible, as they are in the latter, into a series of large "gastropores" and a series of smaller "dactylopores."

I shall more fully describe and figure the minute structure of the skeleton in *S. concentrica*, Goldf., at a later period. It will be evident from the above, however, that the genus *Stromatopora*, Goldf., as typified by the first-described species, viz. *S. concentrica*, Goldf., comprises fossils of an entirely different structure to those which palæontologists have hitherto usually included under this generic name. I shall be able to show that *S. concentrica*, Goldf., is really only one of a very extensive series of forms, abounding in the Silurian and Devonian Rocks, and constituting a well-marked group, for which the name of *Stromatoporidæ* may be employed.

On the other hand, the various fossils which have been placed by palæontologists generally under the head of *Stromatopora*—when this name has been used in a restricted sense—are really of a very different structure, and must be placed under new generic titles. The most characteristic of these, namely the forms understood formerly by Bargatzky, Carter, and others who have specially investigated the subject, as *Stromatoporæ*, may be included under the new genus *Actinostroma*, which will form the type of the group of the *Actinostromidæ*. It follows, further, that whenever in the present work *Stromatopora concentrica*, Goldf., is mentioned, the type understood under this name is the original of Goldfuss, as above described, and is therefore neither generically referable to what has been previously understood as *Stromatopora*, nor specifically identical with the forms which have usually been regarded as constituting *S. concentrica*, Goldf.

Before leaving the subject of the nature of the original specimens of *Stromatopora concentrica*, Goldf., I may mention that the Bonn Museum contains a third specimen, which is believed to have been in Goldfuss's view when he described this species. Being unfigured, this specimen has, of course, no authority as compared with the figured specimen above described, which we must take as the real type of *S. concentrica*, Goldf. It is worth noting, however, that the specimen here alluded to, though in its general aspect and superficial characters very like the true *S. concentrica*, is in reality of a totally different structure. It has the

form of a hemispherical mass, composed of concentrically disposed strata of considerable thickness (" latilaminæ "), its texture being so dense as to exhibit the minute structure but imperfectly under the lens.[1] Examined microscopically, the skeleton is seen not to be composed of a continuously reticulated fibre, but to be built up of definite " radial pillars," which are united at regular intervals by radiating horizontal connecting-processes or " arms," thus constituting a series of " concentric laminæ." It has, therefore, the so-called " hexactinellid structure," which is characteristic of all those Stromatoporoids which were formerly referred to the genus *Stromatopora*, and for which I shall now propose the generic title of *Actinostroma*. Specifically, it is identical with, or very closely allied to, the form which Bargatzky has erroneously identified ('Stromatoporen des rheinischen Devons,' p. 56) with *Stromatopora astroites*, Rosen.

(2) *Tragos capitatum*, Goldf. ('Petref. Germ.,' p. 13, Taf. v, fig. 6). This was originally described by Goldfuss as a distinct species, but was subsequently (in a later portion of the 'Petrefacta') referred by him to his *Stromatopora polymorpha*. The original specimen shows that this form possesses the continuously reticulated skeleton and the minutely porous skeleton-fibre which characterise the group of the *Stromatoporidæ* proper; and it must be referred either to *Stromatopora*, Goldf., itself or to some allied genus. Thin sections of the original specimen do not exist, but I have collected from the Devonian Limestones of the Paffrath district a number of examples of apparently the same species, and a minute examination of these has led me to think that the species should probably be referred to the genus *Idiostroma*, Winchell. In any case the species is one quite distinct from the true *Stromatopora concentrica*, Goldf.

(3) *Ceriopora verrucosa*, Goldf. ('Petref. Germ.,' p. 33, Taf. x, fig. 6). In the later portion of his work Goldfuss referred this form also to *Stromatopora polymorpha*. A superficial examination of the original specimen shows that this type is really referable to what I shall now term *Actinostroma* (*i. e.* to what has previously been regarded as *Stromatopora* proper), the skeleton being made up of " radial pillars " and horizontal connecting-processes. It is a good species, and is common at certain localities in the Rhenish Devonians (*e. g.* at Büchel). It will stand as *Actinostroma verrucosum*, Goldf. sp.

(4) *Stromatopora polymorpha*, Goldf. Under this name Goldfuss included a number of quite distinct forms which are at present only partially known. The forms in question are as follows:

(*a*) A group of encrusting forms ('Petref. Germ.,' Taf. lxiv, figs. 8 *a*, 8 *c*, 8 *d*), which seem to be referable to what I shall subsequently define as *Stromatoporella*. They are common in the Devonian Limestone at Büchel, and we may follow

[1] Precisely similar specimens are abundant at Gerolstein in association with the true *S. concentrica*, Goldf., the latter being, however, much less common.

Bargatzky in retaining for them the specific name of "*curiosa*," which Goldfuss gave to them as a variety of *S. polymorpha*.

(*b*) A massive form having the surface covered with perforated nipple-shaped eminences ('Petref. Germ.,' Taf. lxiv, fig. 8, *f*), subsequently distinguished by Bargatzky as *S. polyostiolata*. This form is only imperfectly known, and it is not at present possible to state definitely what are its complete characters. Through the kindness of Professor Schlüter I have been able to examine a thin section of the original specimen, and I am able to say that it belongs to one of the groups of the Stromatoporoids in which the skeleton is completely reticulated and the skeleton-fibre is minutely porous. I have little doubt that the species (as based on the original specimen) is really referable to *Stachyodes*, Barg., with which it agrees entirely in the minute structure of the skeleton-fibre. In any case it is entirely distinct from the other forms included by Goldfuss under the name of *S. polymorpha*.

(*c*) The form for which Goldfuss used the varietal name of "*ostiolata*" ('Petref. Germ.,' Taf. lxiv, fig. 8, *e*), and which Bargatzky subsequently raised to the rank of a distinct species under the name of *S. monostiolata*. The single original specimen has never been sectioned, and it is therefore impossible to come to any positive conclusion as to its internal structure or its real affinities.

It would appear from the above that Goldfuss included probably three distinct forms under the name of *S. polymorpha*. If one were disposed to retain the specific title of "*polymorpha*" at all, it would be probably best to do so for the forms which Bargatzky has called *S. curiosa*, but it would appear to be best to drop the name altogether. An additional reason for following this course is that Goldfuss himself, in the 'Petrefacta,' ultimately referred his *Tragos capitatum* to *S. polymorpha*, the former thus becoming the first described example of *S. polymorpha*, and therefore the type of the species. Goldfuss also ultimately referred his *Ceriopora verrucosa* to *S. polymorpha*. Upon the whole, therefore, any attempt to retain the species would be sure to lead to confusion.

Prof. Ferd. Roemer has expressed the opinion ('Rhein. Uebergangsgebirge,' p. 57, 1844) that *Stromatopora concentrica*, Goldf., and *S. polymorpha*, Goldf., are identical. I have examined in the Bonn Museum the specimen upon which Roemer relied in making this statement, and it seems certainly (so far as can be judged without thin sections) to belong to the true *S. concentrica*, Goldf. As, however, the specimen in question is not one of the originals upon which Goldfuss founded his *S. polymorpha*, and as it does not agree in any of its obvious characters with any of these originals, it cannot be accepted as throwing any light upon the validity of this species.

Having now dealt at some length, as the importance of the subject demanded, with the species of Stromatoporoids described and figured by Goldfuss, I may

more briefly summarise the history of the group since the appearance of the 'Petrefacta Germaniæ' in 1826.

In the year 1833, de Blainville referred *Stromatopora*, with some doubt, to the Corals ('Manuel d'Actinologie,' p. 413).

In 1834, Steininger ('Mém. de la Soc. Géol. de France,' tom. i) described some species of Stromatoporoids from the Eifel Limestone. One of these, which he termed *Alcyonium echinatum*, has been generally identified with *Actinostroma* (*Stromatopora*) *verrucosum*, Goldf. The genus *Stromatopora* was referred by Steininger to the Sponges.

In the 'Silurian System' (1839), Mr. Lonsdale gave a list, accompanied by figures, of the Silurian Corals, and among these he described two species of Stromatoporoids under the names *S. concentrica*, Goldf., and *S. nummulitisimilis*, Lonsd. The former of these cannot be certainly identified from the description and figure given ('Sil. Syst.,' p. 680, pl. xv, fig. 31), there being at least two species in the Wenlock Limestone of Britain, which might have served as Lonsdale's type. An examination, however, of Lonsdale's original specimen, now preserved in the British Museum, shows it to be really one of the most beautiful and characteristic of the Wenlock Stromatoporoids, and properly referable to the genus *Clathrodictyon*. As d'Orbigny subsequently named Lonsdale's species *Stromatopora striatella*, this form will now stand as *Clathrodictyon striatellum*, d'Orb. sp. The second form described by Lonsdale, viz. *S. nummulitisimilis*, is not organic, but was founded upon specimens of the pisolitic limestone which forms part of the series of the Wenlock Limestone at Colwell, near Ledbury.

In addition to the above, Lonsdale described and figured a third Stromatoporoid from the Wenlock Limestone, under the name of *Porites discoidea* ('Sil. Syst.,' p. 688, pl. xvi, fig. 1). The true nature of the fossil so named certainly could not have been recognised from the description or figure given of it; and it is not surprising that in the later editions of 'Siluria' it should have been doubtfully placed under *Heliolites*. The original specimen of *Porites discoidea*, Lonsd., now in the British Museum, can, however, be at once shown to be, as long since surmised by Lindström, a genuine Stromatoporoid. The internal structure of the figured specimen has been, unfortunately, so far destroyed by secondary crystallisation that thin sections yield no conclusive evidence as to its true nature and affinities. Judging, however, from its external characters, there can be little hesitation in identifying the species with the form described by von Rosen under the name of *Stromatopora elegans*. This is a true *Stromatopora*, Goldf. (in the sense previously defined), and the species will therefore stand as *Stromatopora discoidea*, Lonsd. sp.

In 1840, Mr. Lonsdale published some further observations on the Stromatoporoids ('Trans. Geol. Soc. Lond.,' ser. 2, vol. v). He placed the genus *Stromato-*

pora (as understood by him) among the Corals; and he described and figured, under the name of *Coscinopora placenta*, the singular fossil subsequently and better known as *Caunopora placenta*.

Michelin ('Iconographie Zoöphytologique,' p. 190, pl. 49, fig. 4, 1840—47) described and figured a Stromatoporoid under the name of *Stromatopora concentrica,* Goldf. The figure given would answer fairly for this species, but without an examination of the original specimen it would be of little use to hazard a conjecture as to the precise form which he had before him.

In 1841, Professor Phillips described and figured certain Stromatoporoids from the Devonian formation of Devonshire ('Palæozoic Fossils of Cornwall,' &c., p. 18). The two forms identified respectively as *Stromatopora concentrica,* Goldf., and *S. polymorpha*, Goldf., are certainly not identical with the forms described by Goldfuss under these two names. What they really are could only be determined positively by an examination of the specimens which Phillips had under investigation. The extraordinary fossil described by Lonsdale under the name of *Coscinopora placenta* is here referred to a new genus, viz. *Caunopora.* Under the name of *Caunopora ramosa* Phillips also describes and figures the remarkable form which now constitutes the type of the genus *Amphipora* of Schulz.

In 1843, Fr. Ad. Römer referred certain fossils to the Stromatoporoids, and placed the genus *Stromatopora* itself among the Corals ('Versteinerungen des Harzgebirges'). Judging from his figures, however, the forms to which he assigns the names of *S. concentrica* and *S. polymorpha* are not really referable to the Stromatoporoids at all.

In the same year, Count von Keyserling ('Reise in das Petschora-Land') expressed the opinion that the genus *Stromatopora* is referable to the Corals, and that it is nearly related to *Alveolites*, Lam.

In 1844, Prof. Ferdinand Roemer first brought forward the highly important conjecture that the genus *Caunopora*, Phill., is really based upon specimens of *Syringopora* growing parasitically along with *Stromatopora;* or, to use his own words, that *Caunopora* is "nichts anderes als *Stromatopora polymorpha* von Syringoporen durchwachsen"—('Das rheinische Uebergangsgebirge'). At the same time he expressed the opinion, as previously noted, that *Stromatopora concentrica*, Goldf., is only a form of *S. polymorpha*, Goldf.; and he arrived at the conclusion that almost all the species of Stromatoporoids described by former observers might be regarded as variations of a single type.

In 1844, Prof. M'Coy ('Synopsis Carb. Limestone Foss. of Ireland') described briefly some more or less obscure fossils from the Carboniferous Limestone of Ireland, to which he gives the names of *Caunopora placenta*, Phill., *Stromatopora concentrica*, Lonsd., *S. polymorpha*, Goldf., and *S. subtilis*, M'Coy. The true structure and nature of these must remain at present doubtful.

In 1847, Hall ('Pal. New York,' vol. i, p. 48, pl. xii) founded the genus *Stromatocerium* for a Stromatoporoid from the Trenton Limestone of North America, the structural characters of the genus, however, being left undefined. In the same work (vol. ii, p. 135, 1852) Prof. Hall states that, according to his observations, the skeleton of *Stromatopora* is "composed of minute cylindrical tubes with considerable space between, and that the laminated structure arises from thin layers of calcareous matter deposited and filling the spaces between, and enclosing the tubes." He considers the genus to be referable to the Corals, and to be "more nearly related to *Tubipora* than to any other genus."

In the 'Prodrome de Paléontologie' (1850), d'Orbigny places the genus *Stromatopora* among the Sponges, and names a number of new species, all of which, however, are founded upon forms previously described by other writers. For the Wenlock Stromatoporoid which Lonsdale had erroneously referred to *S. concentrica*, Goldf., he proposed the name of *S. striatella;* and *Tragos capitatum*, Goldf., is removed to *Stromatopora* as *S. capitata*. On the other hand, *S. polymorpha*, Goldf., appears under the guise of no less than five new species, distributed partially under *Stromatopora* and partially under the new genus *Sparsispongia* (viz. *Stromatopora Goldfussii*, *S. sulcata*, *Sparsispongia polymorpha*, *S. radiosa*, and *S. ramosa*). Lastly, *Actinostroma* (*Stromatopora*) *verrucosum*, Goldf., is taken as the genuine *Stromatopora polymorpha* of Goldfuss.

In the subsequently published 'Cours Élémentaire de Paléontologie' (1851), d'Orbigny again expressed the opinion that the Stromatoporoids are referable to the Sponges.

In 1851, Prof. M'Coy expressed the opinion ('Brit. Pal. Foss.,' p. 12) that *Stromatopora* is a true Coral allied to *Fistulipora* and *Heliolites* (*Palæopora*). His definition of the genus is: "Corallum calcareous, forming large amorphous masses composed of very thin superficial layers of minute vesicular tissue of the thickness of one cell each, occasionally marked on the upper surface with extremely obscure, distant, quincuncially-arranged small pits."

In a later portion of the same work (p. 65) M'Coy described, unfortunately only partially with figures, several species of British Stromatoporoids. The forms which he identified as *Stromatopora concentrica*, Goldf., and *S. polymorpha*, Goldf., cannot now be certainly determined without an examination of the original specimens. The former would seem from the description given to be an *Actinostroma*, and the latter is apparently a true *Stromatopora*. The genus *Caunopora* of Phillips is regarded as a subgenus of *Stromatopora*, Goldf., and three species are referred to it, viz. *C. placenta*, Lonsd., *C. ramosa*, Phill. (Brass. MS.), and *C. verticillata*, M'Coy. The last of these three is a remarkable Devonian fossil, which seems to be really identical with the *Stachyodes ramosa* of Bargatzky, from the Devonian Limestones of the Paffrath district.

In 1853, Steininger ('Geognostische Beschreibung der Eifel') described a Stromatoporoid from the Devonian Limestones of the Eifel under the name of *Stromatopora foliata*, referring the genus to the Sponges.

Two species of *Stromatopora* were also described by Fr. Ad. Römer in the 'Palæontographica' (Bd. iii, 1852, and Bd. v, 1855) under the names of *S. patella* and *S. polymorpha*, var. *stellifera*. The true nature of these forms is, however, uncertain.

The two Sandbergers ('Die Versteinerungen des rheinischen Schichtensystems in Nassau,' p. 380, 1850—56) express the opinion that the genus *Stromatopora* should be referred to the *Polyzoa*, but they base this view upon the untenable supposition that the "radial pillars" served for the lodgment of zoöids.

The same view as to the affinities of *Stromatopora* is expressed by Prof. Ferd. Roemer ('Lethæa Geognostica,' 3rd ed., vol. i, p. 166, 1851—56), who compares the genus with the recent *Cellepora*. In a note, however, Roemer adds that he has since examined specimens of *S. polymorpha* from the Eifel in which he can detect both prismatic tubes and tabulæ, and that it will be therefore necessary to remove the genus *Stromatopora* to the Tabulate Corals, and to place it in the vicinity of *Chætetes* and *Favosites*. This last conclusion was really based (as subsequently pointed out by Roemer himself, 'Lethæa Palæozoica,' p. 460, 1883) upon certain singular corals (*Chætetes stromatoporoides*, Roemer), which commonly have their surface covered by an encrusting Stromatoporoid.

In 1857, Mr. Billings founded the genus *Beatricea* for the reception of certain extraordinary fossils from the Ordovician and Silurian Rocks of North America ('Geological Survey of Canada; Rep. of Progress for 1856,' p. 343, 1857, and 'Canadian Naturalist,' new ser., vol. ii, 1857). Mr. Billings at first held the opinion that *Beatricea* was probably referable to the vegetable kingdom. It will be shown subsequently, however, that the affinities of this remarkable genus are probably with the Stromatoporoids, though the structure of the skeleton is highly anomalous.

In 1858, Magister Friedrich Schmidt described two species of Stromatoporoids from the Silurian Rocks of Esthonia ('Silurische Formation von Ehstland, Nord-Livland und Oesel,' p. 232). One of these he identified with *Stromatopora striatella*, d'Orb., and the other he described as *S. mammillata*, n. sp. The latter is really the previously described *Clathrodictyon striatellum*, d'Orb.

In 1860, Eichwald ('Lethæa Rossica,' vol. i, p. 345) defined *Stromatopora* as a spongy mass, composed of closely approximated lamellæ, and enveloping other organic bodies; its surface being covered with minute rounded pores arranged without order over the whole surface of the skeleton. He seems to have been the first to promulgate the view, afterwards supported by von Rosen, that the skeleton of the Stromatoporoids consisted of a network of *horny* fibres, which had been

replaced by carbonate of lime in the process of fossilisation. He describes *S. polymorpha*, Goldf., var. *constellata*, which he regards as identical with *Stromatopora verrucosa*, Goldf.

In 1862, Mr. Billings described a Stromatoporoid from the Black-River Limestone, under the name of *Stromatopora compacta* ('Palæozoic Fossils,' p. 55). He at first referred the Stromatoporoids to the *Amorphozoa;* but in a later portion of the same work he expressed the opinion that they are Corals, and are allied to *Fistulipora.*

In 1865, Professor Hyatt expressed the opinion ('Amer. Journ. Sci. and Arts') that the singular genus *Beatricea*, Bill., should be placed among the *Cephalopoda*, of which it should be regarded as the type of a special family.

In 1866, Professor Winchell published an important paper on the structure and affinities of the Stromatoporoids ('Proc. Amer. Assoc. for the Advancement of Science,' 1866, p. 91). In this memoir, the author not only discusses the minute structure and systematic position of the Stromatoporoids, but also gives descriptions of four species from the Devonian Rocks (Hamilton group) of Michigan and Ohio.[1] The species described are named *S. pustulifera*, *S. monticulifera*, *S. nux*, and *S. cæspitosa;* but they are, unfortunately, not figured. The two former are stated to be of the general type of *S. polymorpha*, Goldf.; and it is interesting to note the statement of the author that, having examined "ship-loads" of specimens, he has "never detected evidence that they were in any sense encrusting." *Stromatopora nux* is said to be of the same type as *S. concentrica*, Goldf.; and *S. cæspitosa* is a wholly aberrant form, for which a new genus (*Idiostroma*) is proposed. As regards the general affinities of the Stromatoporoids, Professor Winchell comes to the conclusion that they constitute a peculiar group of the true Corals, with relationships to the *Cystiphyllidæ* and *Cyathophyllidæ*. The following is the arrangement of the Stromatoporoids and their subdivisions as proposed by Winchell.

"Family, *Stromatoporidæ*.—Polyps isolated or confluent; exserted, never forming a cup; secreting a corallum which consists of a series of concentric layers (or diaphragms) of vesicular tissue, separated and perforated by vermicular ramifying passages, which are either radially or confusedly disposed. Mural system wanting; lamellar structure distinctly present only in the higher forms.

"Genus, *Idiostroma* (n. gen.).—Polypi completely isolated, forming branching masses; lamellar system represented by a radial structure.

"Species: *I. cæspitosum*, *I. gordiaceum*.

"Genus, *Cœnostroma* (n. gen.).—Polypi confluent, but individualised, forming elongated or spheroidal compound masses; diaphragms common and continuous

[1] These species were originally described by Prof. Winchell in his 'Report on the Grand Traverse Region,' a work to which I have unfortunately not had access.

throughout; lamellar system indicated by the radiate arrangement of the vermicular passages, which commonly diverge from the summits of little eminences raised in the concentric laminæ.

"Species: *C. pustulosum*, *C. monticuliferum*, *C. granuliferum*, *C. polymorphum*, *C. radiosum*, *C. ramosum*.

"Genus, *Caunopora* (Phillips).—'Corallum polymorphous, composed of minute, irregular, vermicular, cellulose tissue, disposed in obscure concentric layers, traversed by a few long, larger, variously disposed, vermiform, cylindrical channels' (M'Coy, 'Brit. Pal. Foss.,' p. 66).

"Species: *C. placenta*, *C. ramosa*, *C. verticillata*.

"Genus *Stromatopora* (Goldf.).—Polypi confluent, with individualities sensibly obliterated. Corallum consisting essentially of confluent diaphragms, or concentric layers, which generally inclose a foreign body—being secreted on all sides of it, and forming a spheroidal mass.

"Species: *S. concentrica*, *S. striatella*, *S. nux*, *S. rugosa*, *S. compacta*, *S. nummulitisimilis*."

With regard to the two new genera proposed by Professor Winchell in the above-quoted synopsis, *Idiostroma* is an exceedingly abnormal form, and the absence of figures illustrative of the minute structure may sufficiently explain why the type has not been recognised by subsequent observers. The type of the genus, viz. *I. cæspitosum*, Winch., is described as resembling a large cæspitosely-branched Cyathophylloid Coral, forming masses three or four feet in diameter, composed of stems which vary from one fifth to one third of an inch in diameter, and which may be either apart or in contact with another. The exterior is "longitudinally vermicular-striate." The transverse section "exhibits a radiating structure, as in the *Cyathophyllidæ;* but there is no outer wall or definite limitation to the structure, and the interior is completely filled with concentric circles of coralline substance except a small perforation in the centre." In the absence of a more detailed account of the minute structure, it would, as above remarked, be difficult to decide positively as to the true relationships of this singular type. I have, however, collected a number of specimens from the Devonian Limestone of Hebborn, in the Paffrath district, which seem to be unquestionably congeneric with *Idiostroma cæspitosum*, Winch.; and I shall subsequently give a description of the characters of the genus as elucidated by these examples.

The genus *Cœnostroma*, Winchell, on the other hand, comprises Stromatoporoids of the normal type, and the only really distinctive feature in the diagnosis of the genus, as given by its founder, is the presence of "astrorhizæ," or radiately disposed canal-systems (the "polypi" of Winchell's definition). As will be subsequently seen, however, such stellate canals are developed in a large number of Stromatoporoids, in which the minute structure is otherwise exceedingly different;

and the mere presence of such canal-systems does not, therefore, afford a sufficient ground for generic distinction. Indeed, it occasionally happens that certain individuals of a given species exhibit such "astrorhizæ," while in other individuals of the same species these structures are wanting, or are, at any rate, not conspicuous. I am, therefore, of opinion that the genus *Cœnostroma,* Winch., cannot be retained with advantage.

One of the most important contributions to the study of the Stromatoporoids is that published by Baron von Rosen in 1867, under the title 'Ueber die Natur der Stromatoporen, und über die Erhaltung der Hornfaser der Spongien im fossilen Zustande.' In this work, the author recounts the results of an investigation into the structure of the Stromatoporoids by means of thin sections prepared for the microscope; and the value of his memoir is further enhanced by a number of excellent plates, dealing principally with the minute structure of the skeleton. The material upon which von Rosen based his work was derived from the Upper-Silurian Rocks of the north of Europe, from which he describes several new species.

Having recently had the opportunity of examining in Dorpat the original specimens and slides upon which von Rosen founded his species, and having myself collected a large series of the same forms, I shall be able later to discuss more fully the characters and affinities of these species. In the meanwhile the following brief remarks may be made as regards some of them.

Stromatopora typica, Rosen (op. cit., Taf. I, fig. 1), is a species common in the Wenlock Limestone of Britain, and is a true *Stromatopora* (in the sense previously defined). The type-specimen of *Stromatopora astroites,* Rosen, has its internal structure almost destroyed, as the result of crystallisation; but other specimens included by Rosen under this name are apparently identical with *S. typica,* and the specific name of *astroites* must therefore be abandoned in favour of *typica.* *Stromatopora elegans,* Rosen, though much crystallised, appears to be identical with *S. discoidea,* Lonsd., the latter name having the priority. *Stromatopora Schmidtii,* Rosen, is a very peculiar type of the genus *Actinostroma.* The *Stromatopora variolaris* of Rosen is a species of *Clathrodictyon,* and is of common occurrence in the Wenlock Limestone of Britain. *Stromatopora regularis,* Rosen, is also a species of *Clathrodictyon;* and is also found, though rarely, in the Wenlock Limestone of Britain and of Gotland. The remarkable type described under the name of *Stromatopora dentata* appears to be properly referable to a new genus allied to *Labechia,* E. and H., which I shall name *Rosenella.* To this genus also belongs the species described as *Stromatopora Ungeri.* It may be added that von Rosen devotes a section to the discussion of the characters of *S. polymorpha,* Goldf., and, rightly, concludes that Goldfuss had included several types under this specific name.

As regards general results, the main conclusion reached by Von Rosen is that the skeleton of the Stromatoporoids is composed of horny fibres arranged in bundles, and that these organisms are referable to the group of the Keratose Sponges, or allied to these. The minute openings on the surface of many Stromatoporoids he regards as "pores," and the larger openings, which are occasionally present, as "oscula." In this latter view, he has been preceded by D'Orbigny and others, and has been followed by many later investigators. In his opinion that the skeleton of the Stromatoporoids was in reality of a horny nature, Von Rosen was preceded by Eichwald; but there can be no hesitation, in the light of all known facts, in unequivocally rejecting this view. In spite of the above erroneous conclusion as to the composition of the skeleton of the Stromatoporoids, Von Rosen's work will continue, justly, to retain its position as a classical treatise upon a most difficult group of organisms.

In 1870, Dr. Gustav Lindström published a valuable paper on the *Anthozoa perforata* of Gotland ('Kongl. Svenska Vetenskaps-Akad. Handlingar,' Bd. ix), in which he describes and figures the *Porites discoidea* of Lonsdale as a Stromatoporoid, under the name of *Cœnostroma discoideum.* An examination of the original specimen, now preserved in the British Museum, has shown that Dr. Lindström is perfectly correct in the belief that *Porites discoidea*, Lonsd., was really founded upon a Stromatoporoid. I should be disposed, however, to think that in his description of this species, Dr. Lindström has included more of the Wenlock Stromatoporoids than Lonsdale's species, and, for reasons above given, I am unable to retain the genus *Cœnostroma*, Winch. In Lindström's opinion, *Cœnostroma* is a true Coral, and is allied to the *Montiporinæ.* On the other hand, he regards the genus *Stromatopora,* Goldf., as distinguished from *Cœnostroma*, Winch., as having quite different affinities, and as being probably related to the *Foraminifera.*

In a memoir on the affinities of the *Anthozoa tabulata* ('Œfversigt af Kongl. Vetenskaps-Akad. Förhandl.,' 1873, translated in the 'Annals of Natural History,' 1876), Dr. Lindström expresses the opinion that *Cœnostroma*, Winchell, presents certain points of likeness to *Labechia*, E. and H. He further makes the very important suggestion that the genus *Labechia* is of Hydrozoal affinities, and is related to the recent genus *Hydractinia.* To Dr. Lindström, therefore, belongs, so far as I am aware, the credit of having first publicly pointed out the direction in which the true relationships of the Stromatoporoids might be looked for.

In the 'Twenty-third Annual Report on the State Cabinet,' dated 1873, Prof. Hall and Mr. Whitfield describe as new species five Stromatoporoids from the Devonian Rocks (Chemung group) of North America. These are named *Stromatopora erratica*, *S. expansa*, *S.* (*Cœnostroma*) *incrustans*, *S.* (*Cœnostroma*) *solidula*, and *Caunopora planulata.* It would not appear that the last of these is really of the same nature as the fossils referred properly to *Caunopora*, Phill, as it seemingly does not possess the *walled* tubes which are characteristic of the latter.

In 1873, Mr. Salter expressed the opinion that *Stromatopora* is "a very solid calcareous Sponge" ('Cat. Sil. Foss.,' p. 99).

In the same year, the present writer described ('Ann. and Mag. Nat. Hist.,' ser. 4, vol. xii) several Stromatoporoids from the Silurian and Devonian Rocks of Canada. In one of these, viz. *Clathrodictyon* (*Stromatopora*) *ostiolatum*, Nich., the presence of regularly-disposed round apertures of large size was pointed out, and it was suggested that these corresponded with the "oscula" of Sponges.

In 1874, the present writer further discussed ('Ann. and Mag. Nat. Hist.,' ser. 4, vol. xiii) the affinities of the Stromatoporoids, referring them to the *Calcispongiæ,* and indicating the presence in various species of large openings, which might be regarded as of an "oscular" nature. The skeleton was regarded as "composed of an amalgamated system of horizontal spicules, separated by interspaces, and kept apart by a vertical system of delicate calcareous rods, giving rise to a system of more or less quadrangular tubes." In the 'Report on the Palæontology of the Province of Ontario' (1874) the same opinion is repeated. In the 'Palæontology of the State of Ohio' (vol. ii, 1875) the writer described several species of Stromatoporoids from the Devonian Rocks of Ohio, and proposed two new genera under the names *Syringostroma* and *Dictyostroma*. The type of *Syringostroma* is the singular *S. densum,* which possesses the reticulated skeleton characteristic of *Stromatopora,* Goldf., but which has certain peculiarities of its own. I shall later on discuss the value of these peculiarities. Besides *S. densum*, Nich., another remarkable form was placed under *Syringostroma,* under the name of *S. columnare,* Nich. This latter, however, is really quite distinct in its structure, and forms the type of the genus *Stylodictyon,* Nich. and Mur. The genus *Dictyostroma* was proposed for a remarkable Stromatoporoid from the Silurian Rocks of Kentucky; but as the minute structure of the skeleton is still unknown, it is doubtful whether this genus can be retained.

In the 'Dawn of Life' (1875), Principal Dawson incidentally gives the result of his observations on the structure of *Stromatopora* and its allies, regarding them as connected on the one hand with the *Foraminifera* and on the other hand with the Sponges. He compares the astrorhizal tubes of certain Stromatoporoids with the "canal-system" of *Eozoön.*

In a memoir upon the genus *Stauronema,* Prof. Sollas ('Ann. and Mag. Nat. Hist.,' ser. 4, vol. xix, 1877) places *Stromatopora* among the Vitreo-hexactinellid Sponges. In a subsequent paper ('Quart. Journ. Geol. Soc.,' 1877), the same author expresses the opinion that under the head of *Stromatopora* are included organisms of very different affinities, some being Siliceous Sponges, some related to *Millepora* and *Hydractinia*, and some with relationships as yet undetermined.

In 1877, Mr. Carter expressed the opinion ('Ann. and Mag. Nat. Hist.,' ser. 4, vol. xix) that the Stromatoporoids are closely related to the living *Hydractinia,*

and that the extinct genus *Parkeria*, described by Dr. W. B. Carpenter as a Foraminifer, is also truly Hydrozoal and related to *Hydractinia*. This memoir is the first of a long and important series of papers in which Mr. Carter deals with the recent *Hydractiniæ* and their extinct allies, and the result of which has been the gradual conversion of palæontologists to the view that the Stromatoporoids are properly referable to the *Hydrozoa*. Leaving *Parkeria* out of the question, as not concerning us here, Mr. Carter in the memoir alluded to describes various recent and fossil species of *Hydractinia*, and gives an excellent account of the structure, and also of the development, of the skeleton of *Hydractinia echinata*, Flem. He maintains the opinion that the Stromatoporoids are extinct allies of *Hydractinia*, and that they have nothing in common with the Sponges, to which they have been referred by so many previous writers. The stellate canals ("astrorhizæ") which constitute such a conspicuous feature in many Stromatoporoids, and which superficially exhibit such a sponge-like appearance, are parallelled by Mr. Carter with the shallow, radiating, cœnosarcal grooves which furrow the surface of the crust in the recent *Hydractiniæ*.

In a supplementary note to the English translation ('Ann. and Mag. Nat. Hist.,' ser. 4, vol. xix, 1877) of his masterly memoir, entitled "Beiträge zur Systematik der fossilen Spongien" ('Neues Jahrbuch für Mineralogie,' &c., 1877), Professor Zittel gives his adhesion to Mr. Carter's view that the Stromatoporoids are really to be regarded as allies of *Hydractinia*, and as belonging therefore to the *Hydrozoa*.

In an interesting and valuable memoir published in 1878 ('Palæontographica,' 3 Folge, Bd. i, 3 Lief., p. 101), Dr. Steinmann also expresses the opinion that the Stromatoporoids should be placed in the neighbourhood of the *Hydractiniidæ*. The author founds the genus *Sphæractinia* for certain concentrically-laminated fossils from the Upper-Jurassic Rocks, which in internal structure present considerable resemblance to certain of the Stromatoporoids. The genus *Labechia*, E. and H., is regarded as constituting a connecting link between the Tabulate Corals and the *Hydractiniidæ*. The author also deals with *Parkeria*, Carp., *Loftusia*, Brady, and the three new genera *Porosphæra*, *Cylindrohyphasma*, and *Ellipsactinia*, all of which he considers as being related to the *Hydractiniidæ*, and as having, therefore, more or less close relationships with the Stromatoporoids.

In the same year Mr. Carter published a second paper, "On New Species of Hydractiniidæ, recent and fossil, and on the Identity in Structure of *Millepora alcicornis* and *Stromatopora*" ('Ann. and Mag. Nat. Hist.,' ser. 5, vol. i, pp. 298—311). In this memoir the author compares the Stromatoporoids with *Millepora*, and comes to the conclusion that there exists between them a substantial agreement in structure. The stellate canal-systems ("astrorhizæ") of many Stromatoporoids are compared with the irregular cœnosarcal canals which

ramify through the skeleton of *Millepora*, and are regarded as being essentially of the same nature.

In a succeeding number of the same publication ('Ann. and Mag. Nat. Hist.,' ser. 5, vol. i, p. 412), Mr. Carter has a short note on "Calcareous Hexactinellid Structure in the Devonian Limestone," in which he describes specimens from the Devonshire Limestones as showing a structure apparently similar to that of the Hexactinellid Sponges, but calcareous in composition. The specimens in question belonged, doubtless, to Stromatoporoids appertaining to the genus *Actinostroma*, some of these, when examined in certain aspects, presenting an appearance very similar to that of some of the *Hexactinellidæ*.[1]

In a still later number of the same publication ('Ann. and Mag. Nat. Hist.,' ser. 5, vol. ii, p. 28), Principal Dawson opposes the views expressed by Mr. Carter as to the relationships which the latter sought to establish between the Stromatoporoids and *Millepora*.

Later again ('Ann. and Mag. Nat. Hist.,' ser. 5, vol. ii, p. 304, 1878), Mr. Carter returns to the same subject in a paper entitled "On the probable Nature of the Animal which produced the *Stromatoporidæ*, traced through *Hydractinia*, *Millepora alcicornis*, and *Caunopora* to *Stromatopora*." Much of this memoir is, in the main, a repetition of points which had been brought forward by the author in previous communications. Mr. Carter explains that in former papers he had spoken of *Caunopora*, Phill., under the name of *Stromatopora*, and he has now come to the conclusion that *Caunopora* is really intermediate in its characters between *Millepora*, Lam., and *Stromatopora*, Goldf. The tubes of *Caunopora* he regards as being inhabited by polypites, and as being comparable with the "gastropores" of *Millepora*.

Also in the year 1878, but prior to the appearance of most of the memoirs just noted, a paper on "The Minute Structure of the Skeleton of *Stromatopora* and its Allies," was published by Dr. Murie and the present writer ('Journ. Linn. Soc.,' vol. xiv, 1878). In this memoir, after a historical summary, the authors treat of the general structure of the Stromatoporoids, and bring forward evidence to show that the skeleton of these organisms was certainly originally calcareous. Being at that time unacquainted with the minute structure of the skeleton of the original specimen of *Stromatopora concentrica*, Goldf., the authors followed all previous writers in considering the genus *Stromatopora*, Goldfuss, as comprising those types which possess definite "radial pillars" united by periodically-developed horizontal connecting processes. The genus *Clathrodictyon* was proposed for certain Stromatoporoids with short and irregular "radial pillars," and two species of the

[1] It may be noted that, in certain states of preservation, the singular Coral described by Roemer under the name of *Chætetes stromatoporoides*, also exhibits appearances curiously like those shown by certain Hexactinellid Sponges. This Coral occurs in the Devonian of both Devonshire and Germany.

same, viz. *C. vesiculosum* and *C. cellulosum*, were briefly defined. The genus *Stylodictyon* was founded for the singular *S. columnare*, Nich., and a second species was included in the genus under the name of *S. retiforme*, Nich. and Mur. The latter, however, is really a member of the genus *Actinostroma*, and is closely related to the *A. verrucosum*, Goldf., of the European Devonian Rocks. The genus *Pachystroma* was proposed for certain curious Stromatoporoids of which the new species *P. antiquum*, from the Niagara Limestone of North America, was taken as the type. A recent examination, however, of thin sections of the original specimens of *Stromatopora concentrica*, Goldf., has shown that the genus *Pachystroma*, Nich. and Mur., is nothing more than the veritable *Stromatopora*, Goldf. (non *Stromatopora*, auct.), and the name *Pachystroma* must, therefore, be abandoned. An attempt was made to revive the genus *Stromatocerium*, Hall, upon the basis of a new species (*S. canadense*, Nich. and Mur.) from the Trenton Limestone of Canada. Further and more extended observations have shown, however, that this type is really a *Labechia* in a peculiar condition of preservation. Lastly, the authors accepted the genus *Caunopora*, Phill., as comprising independent organisms. With regard, finally, to the question of the systematic relationships of the Stromatoporoids, the authors came to the conclusion that, in the absence of any demonstration of the existence in any of the Stromatoporoids of definite zoöidal tubes, the reference of these organisms to the *Hydrozoa* cannot be unconditionally accepted. They concluded, therefore, that with the evidence at that time available, the Stromatoporoids may be best regarded as a separate section of the Calcareous Sponges, for which they proposed the name of *Stromatoporoidea*.

In his 'Petrefaktenkunde Deutschlands' (Schwämme, Pls. 141, 142, 1878), Professor Quenstedt treats of the Stromatoporoids among the Sponges. He describes and figures a number of species, mostly from North America; but it is in most cases difficult to identify the species which he had in view. The species which he names *Stromatopora verruculosa* seems, as conjectured by Bargatzky, to be really one of the forms included by Goldfuss under the head of *S. polymorpha*, and the form which he terms *S. striatella*, D'Orb., seems to be really the *S. discoidea* of Lonsd. (= *S. elegans* Rosen) The form described as *S. Wortheni*, Rom., is unquestionably identical with that which I described from the Corniferous Limestone of Ohio, under the name of *Stylodictyon* (*Syringostroma*) *columnare*.[1] The form named *Stromatopora cæspitosa* is the *Idiostroma cæspitosum* of Winchell, and should be placed in *Idiostroma*. The other forms described are *Stromatopora textilis*, Rom., *S. minuta*, Winch., *S. pustulifera*, Winch., and *S. consors*, Quenst., all from the Silurian and Devonian Rocks of North America.

[1] I have not been able to discover that any description of this species has been published by Rominger.

In the year 1879 appeared several memoirs dealing with the Stromatoporoids. One of these was a memoir by Principal Dawson on "The Microscopic Structure of the Stromatoporidæ" ('Quart. Journ. Geol. Soc.,' vol. xxxv, pp. 48—66), in which he maintained his previously-expressed opinion as to the Rhizopodal affinities of these organisms. He altogether rejects the asserted relationship between the Stromatoporoids and the *Hydractiniidæ*, as supported by Carter and Steinmann. Two new species are described under the names of *Caunopora hudsonica* and *Cœnostroma galtense;* and the *Stromatopora compacta* of Billings is stated to be apparently a true Coral. The author considers that the Stromatoporoids "have apparently always been calcareous when recent." Lastly, the author has some remarks upon some of the genera of the Stromatoporoids, in which he adopts *Cœnostroma*, Winch., in much the same sense as that of its original founder, but includes under *Caunopora*, Phill., forms which have not usually been placed in that problematical genus.

In the same publication ('Quart. Journ. Geol. Soc.,' vol. xxxv, p. 67) Mr. Champernowne has a "Note on some Devonian Stromatoporidæ from Dartington, near Totnes." This note deals chiefly with the mode of occurrence of Stromatoporoids in the dolomitic limestone of Dartington; but the author makes the interesting observation that in certain specimens of *Caunopora* he has seen the tubes not to be open, but to be lamelliferous, and to present "some appearance of a columella." With regard to the affinities of the Stromatoporoids, the author concludes that "it is difficult to regard them as forming a compact group of *Calcispongiæ*," and adds—what later observations have fully borne out—that they "clearly seem to embrace structures similar to that of the *Milleporidæ*."

In the 'Annals and Magazine of Natural History' (ser. 5, vol. iv, p. 101, 1879) Mr. Carter published a paper on "The Mode of Growth of Stromatopora, including the Commensalism of Caunopora." In this paper he maintains that *Stromatopora* is essentially an encrusting organism, "not only entering into and filling up the open interstices of other calcareous organisms during their growth, but enveloping their detritus." This view is, however, based upon a study of Stromatoporoids of particular species, or growing under particular conditions. There is, of course, no doubt that Stromatoporoids very commonly do enclose and envelop other organisms of all sorts in the course of their growth, and they also occasionally form thin crusts parasitically attached to foreign bodies. A very large number of the Stromatoporoids, however, have an epithecate base, with a single narrow peduncle of attachment, and are no more given to surround other organisms than are the species of *Alveolites* or *Favosites*, which occur in the same strata. Mr. Carter also now expresses his conviction that the genus *Caunopora*, Phill., is (as long previously maintained by Ferdinand Roemer) really founded upon speci-

mens of some Coral or other organism enveloped in a Stromatoporoid, the "tubes" of *Caunopora* being thus adventitious structures.

In a further communication ('Ann. and Mag. Nat. Hist.,' ser. 5, vol. iv, p. 253, 1879) Mr. Carter returns to the subject of the structure of the skeleton in the Stromatoporoids. He follows Von Rosen in distinguishing two principal types of structure in the skeleton, viz. a "curvilinear structure" and a "rectilinear structure." Mr. Carter also here modifies his previously-expressed view—a view in which at that time most observers concurred—that the "radial pillars" of the Stromatoporoids were solid; and he comes to the conclusion that they were traversed by an axial canal (as in *Labechia*, E. and H.), but closed superficially. The genus *Labechia*, E. and H., is placed by Mr. Carter close to *Hydractinia*, one ground for this collocation being the supposed encrusting habit of *Labechia*. It may be certainly stated, however, that *Labechia* very rarely assumes an encrusting form, the great majority of specimens being in the form of laminar expansions, with a basal epitheca, and a small point of attachment. Lastly, Mr. Carter notices a peculiarity in the appearance of thin sections of certain specimens of *Stromatopora dartingtonensis*, Cart. (erroneously identified with *S. elegans*, Rosen)—namely, that the stellate canals appear to terminate in the fibre of the cœnenchyma itself; but he gives no satisfactory explanation of this phenomenon. The real reason of this appearance, as will be subsequently more fully shown, is that in this form, as in various others, certain specimens are so preserved that the entire system of canals and internal cavities has been filled with more or less opaque, calcareous or argillaceous sediment, the real skeleton having then been dissolved out, and the spaces thus formed finally filled up with calcite. Hence, in such "reversed" specimens, the canal-system and tubes of the organism have the appearance of being parts of the solid skeleton, while the latter is represented only by transparent calcite, and thus looks as if it had been originally hollow, or as if it represented the original cœnenchymal canals and cells.

In his admirable 'Handbuch der Palæontologie' (Bd. i, Lief. ii, p. 284, 1879), Professor Zittel treats of the Stromatoporoids under the Hydrocorallines. He includes the genera *Labechia*, E. and H., and *Ellipsactinia*, Steinm., in the group of the *Stromatoporoidea*.

Lastly, in 1879 the present writer gave a description, accompanied by figures, of the minute structure of the skeleton of the genus *Labechia*, E. and H. ('Palæozoic Tabulate Corals,' p. 330, Pl. XV, figs. 4, 4*a*). In this description it was pointed out that the "pillars" of *Labechia conferta*, Lonsd., are "primitively tubular, but that the median tube is finally largely or entirely obliterated." With regard to the affinities of *Labechia*, the genus was regarded as doubtfully belonging to the Corals, and was considered as in some respects related to the genus *Fistulipora*, M'Coy.

In 1880, an important memoir was published by Prof. Ferd. Roemer on the genus *Caunopora*, Phill. ('Geological Magazine,' dec. ii, vol. vii, p. 343). As previously mentioned, this veteran palæontologist, as long ago as 1844, expressed the opinion that *Caunopora placenta*, Phill., was founded upon specimens of *Stromatopora concentrica*, which had "surrounded and overgrown the stems of *Syringopora*." In the present memoir, Roemer states that the tubes of *Caunopora* are not, strictly speaking, referable to *Syringopora*, but rather belong to *Aulopora*, especially to *A. repens*. He regards *Caunopora placenta*, Lonsd. sp., as being, therefore, the result of the combined growth of a colony of *Stromatopora* with one of *Aulopora;* the latter extending its tubes upwards, as the former adds new layers to its surface, and thus preventing itself from being entirely covered up and killed. The occurrence of thick masses of *Caunopora* is accounted for on the hypothesis that "the vertical tubes do not necessarily all belong to the same individual of *Aulopora*, but different colonies of these little creeping Corals attached themselves repeatedly to the surface of succeeding concentric layers of *Stromatopora*, and were covered by the succeeding one." He adds further that "in fact, on vertical sections of *Caunopora* the same vertical tubes can never be followed up through the whole mass, but they are mostly only a few lines in length." On this point, however, I am unable to agree with Prof. Roemer. Even in very thick specimens of *Caunopora*, the same tubes may often be traced continuously for long distances, and in laminar specimens, an inch or more in thickness, most, if not all, of the tubes pass directly from the top to the bottom. Roemer, moreover, states that a Silurian Stromatoporoid (which he considers to be *S. striatella*) also occasionally exhibits the structure of *Caunopora*, the tubes in this case also being produced by a species of *Aulopora*. Specimens of this nature, in the author's view, had been previously described from the Drift of Groningen, in Holland, being named *Syringopora filiformis* by Goldfuss ('Petref. Germ.' Taf. xxxviii, fig. 15), and referred by Roemer himself to *Heliolites interstincta* ('Diluvial Geschiebe von Sadewitz,' t. iv, fig. 2 *c*). As regards, finally, the perforated tubercles or eminences which are found on the surface of various Stromatoporoids, Prof. Roemer brings forward an ingenious explanation; namely, he discovered that underneath such openings were sometimes to be found the tubes of species of *Spirorbis*, and he therefore suggests that "the hole on the top of the tubercle is the opening of the canal by which that little animal kept up its communication with the surrounding water, and the tubercle was formed by the bending upwards of the successive layers of *Stromatopora* round the canal." That buried specimens of *Spirorbis* may thus give rise to superficial openings, simulating "oscula," is a point which I can myself confirm, from observations upon various of the Silurian Stromatoporoids. Moreover, successive generations of *Spirorbes* may in this way become embedded in the skeleton of a Stromatoporoid, and they often assume a rough grouping in vertical lines.

On the other hand, as I shall point out more fully later on, this explanation by no means applies to such openings as are observable in *Stromatopora ? polyostiolata*, Barg., *Stromatoporella granulata*, Nich., and various other types, in which rounded apertures are seen to be regularly disposed over the surface, and often to be supported upon prominent "mamelons." In these cases, the superficial openings belong in the strictest sense to the structure of the Stromatoporoids themselves, as can conclusively be shown by the fact that thin vertical sections demonstrate them to be the mouths of approximately vertical, wall-less tubes, which form the axes of successively superimposed groups of "astrorhizæ."

In 1880, Mr. Carter published a paper ('Ann. and Mag. Nat. Hist.,' ser. 5, vol. vi, p. 339) in which he criticised the memoir just mentioned. Contrary to the views of Roemer, he expressed the opinion that the tubes of *Caunopora* can not be ascribed to *Aulopora repens*, as an invariable rule at any rate, as they sometimes possess infundibuliform tabulæ, resembling the tabulæ of *Syringopora.* Much stress, however, cannot really be laid upon this argument, as undoubted species of *Aulopora* can be shown to sometimes possess funnel-shaped tabulæ. In the same paper, Mr. Carter proposes the convenient name of "astrorhizæ," for the stellate cœnosarcal canals of certain of the Stromatoporoids; and he describes a Stromatoporoid from Devonshire, under the name of *Stromatopora dartingtonensis*, in which he has detected transverse plates, resembling "tabulæ," in the branches of the astrorhizæ. As to the occurrence of these transverse calcareous partitions in the branches of the astrorhizæ, no doubt whatever is possible. I am, however, unable to accept Mr. Carter's conclusion that these structures are in any way comparable with the "tabulæ" in the tubes of the "gastrozoöids" of *Millepora*, a view which he further maintains in the present memoir. For one thing, many Stromatoporoids (such as the *Stromatoporidæ* generally) really do possess other structures comparable with the "tabulæ" of *Millepora.* Moreover, to accept this view would, as it seems to me, entirely upset the much more reasonable comparison of the "astrorhizæ" of the Stromatoporoids to the branched cœnosarcal grooves of *Hydractinia* and to the irregularly-divided canal-system of the general skeleton of *Millepora*—a comparison which has been ably supported by Mr. Carter himself.

In the 'Neues Jahrbuch für Mineralogie,' &c. (Jahrg. 1880, Bd. ii, p. 403), Dr. Steinmann reviews Mr. Carter's previously noted paper on *Caunopora.* He expresses the opinion that Ferd. Roemer and Carter are correct in their conclusion that the genus *Caunopora* is founded upon specimens in which a Stromatoporoid and a Coral are associated as commensals.

The principal work dealing with the Stromatoporoids, which appeared in the year 1881, is the elaborate memoir by Dr. August Bargatzky on the Stromatoporoids of the Rhenish Devonian formation ('Die Stromatoporen des rheinischen Devons,' Bonn, 1881). I shall have occasion to frequently refer to this memoir,

which is, unfortunately, insufficiently illustrated, but which is otherwise a very valuable and important contribution to the subject; so I need here only indicate its general scope. Commencing with a historical summary, the author next gives a detailed account of the general structure of the skeleton in the Stromatoporoids. He describes this structure as consisting of a series of horizontal and vertical, or concentric and radial, elements; and expresses the view that *Caunopora*, Phill., is the only type of the Stromatoporoids in which the skeletal elements are disposed indifferently, so as to give rise to a "curvilinear" or round-meshed structure. The "radial pillars" he regards as invariably solid, and he states that he has never observed them to open by apertures on the surface. The pores in the concentric laminæ are regarded as having served for the exit of polypites; and Carter's views as to the homology between the astrorhizæ and the cœnosarcal canals of *Hydractinia* are accepted. The existence in some forms of vertical wall-less tubes, which give off the astrorhizæ of successively superimposed interlaminar spaces, is noted; and it is rightly pointed out that these have nothing to do with the walled tubes of *Caunopora*. The absence of such a central vertical tube in the astrorhizæ of various Stromatoporoids is further shown to be due to the fact that in these forms the astrorhizæ of successive interlaminar spaces do not lie above one another, or correspond in position. With regard to *Caunopora*, Phill., Bargatzky considers that two distinct groups have been included under this name. In one of these groups, the general skeleton has a "curvilinear" structure, and to such forms he would restrict the name *Caunopora*. In the other group, the skeleton has a "rectilinear" structure (really only partially so), and for forms of this type he proposes the new genus *Diapora*. As regards both *Caunopora* and *Diapora*, Bargatzky concludes that the walled tubes are *not* foreign to the organism in which they occur; and he gives various detailed reasons for this view. The genus *Parallelopora*, the characters of which I shall discuss subsequently, is founded by Bargatzky for some Stromatoporoids from the Devonian Rocks of the Paffrath district. The next section of Dr. Bargatzky's memoir is occupied with descriptions of the species of Stromatoporoids which occur in the Devonian Rocks of the Rhenish region. Owing to the fact that he had not examined thin sections of the original specimens of Goldfuss, Bargatzky has fallen into the same error as all who had preceded him with regard to *Stromatopora concentrica*, Goldf. He selects, namely, for this classical species the common Devonian Stromatoporoid with the "rectilinear" or "hexactinellid" structure, that is to say, with continuous "radial pillars" and with periodically-developed horizontal connecting-processes. I have examined his named specimens in the Bonn Museum, and he has also been so good as to show me the specimens in his own collection, so that I can speak positively on this point. As a matter of fact, however, as previously pointed out, the true *Stromatopora concentrica* of Goldfuss

has a reticulated skeleton, with the typical "curvilinear" structure, and belongs, therefore, to an entirely different group of the Stromatoporoids to that which includes the forms with a "rectilinear" structure (*i. e.* the *Actinostromidæ*). It follows, therefore, that *Stromatopora concentrica*, Barg., has no relationship with *Stromatopora concentrica*, Goldf. Of the other forms placed by Bargatzky under the genus *Stromatopora*, *S. verrucosa*, Goldf., is likewise a typical *Actinostroma*, with continuous "radial pillars" and a well-marked hexactinellid structure; and this is also the case with the forms named by Bargatzky *S. papillosa*, n. sp., and *S. astroites*, Rosen. The latter of these has really nothing to do with the form described by Rosen as *S. astroites*, but it is a well-marked and perfectly distinct species of the genus *Actinostroma*, of which the former is probably only a variety. On the other hand, the form described as *S. Beuthii*, Barg., is a genuine *Stromatopora*, as above defined, and appears to be a good species. The forms included by Goldfuss under the head of *S. polymorpha* are broken up by Bargatzky into the three species *S. curiosa*, *S. monostiolata*, and *S. polyostiolata*. The two forms included by Bargatzky under the names of *Caunopora placenta*, Phill., and *C. Hüpschii*, Barg., appear to me to be undoubtedly the same; and as I shall subsequently give reasons for not retaining the name of "*placenta*," Phill., the species should stand as *Stromatopora Hüpschii*, Barg., sp. The specimen in the Bonn Museum labelled *Caunopora bücheliensis*, Barg., appears to me also to be identical with the preceding. As, however, Dr. Bargatzky sent me authentic specimens of his *Caunopora bücheliensis*, which are quite different from his *C. Hüpschii*, and as these specimens belong to a form of common occurrence in the Devonian Rocks of Germany and of Britain, I shall retain this specific name, placing the species under *Stromatopora*. Of the species referred to *Parallelopora*, Barg., *P. ostiolata* is a remarkable form, which I shall notice later on; but *P. stellaris*, and *P. Goldfussi* are not so clearly distinct, and the latter may be only the *Stromatopora capitata* of Goldfuss. *P. eifeliensis*, Barg., appears to be a *Fistulipora*. Finally, as regards the systematic position of the Stromatoporoids, Bargatzky agrees with Steinmann and Carter in placing these organisms in the neighbourhood of the *Hydractiniidæ*.

In a second paper ('Zeitschr. der deutscher geol. Gesellschaft,' Jahrg., 1881), Dr. Bargatzky describes a singular Stromatoporoid from the Devonian Limestone of Hebborn, near Paffrath, under the name of *Stachyodes ramosa*. The characters of the new genus *Stachyodes* I shall consider in detail later on. The *species* is identical with the *Stromatopora verticillata* of M'Coy.

In the 'Eleventh Report on the Geology of Indiana,' 1881, p. 400, Prof. James Hall figures a Stromatoporoid under the name of *Stromatopora pustulifera*?, Winchell, and quotes a previously published description of the same by Winchell.

In the 'Twelfth Report on the Geology of Indiana,' 1882, p. 263, Prof. Hall figures a Stromatoporoid, which he considers as probably identical with *Syringostroma densum*, Nich.

In 1881, 1882, and 1883, Monsieur E. Dupont published three successive papers on the structure of the Devonian and Carboniferous Limestones of Belgium, viz. (1) "Sur l'Origine des Calcaires Devoniens de la Belgique," 1881; (2) "Les Iles Coralliennes de Roly et de Philippeville," 'Bull. du Musée Royal d'Hist. Nat., t. i, 1882;' and (3) "Sur les Origines du Calcaire Carbonifère de la Belgique," 1883. In these papers the author draws attention to the very important part played by the Stromatoporoids in the formation of the Devonian Limestones of Belgium, and concludes that these organisms commonly constituted reefs of a similar nature to the coral reefs of the present day. M. Dupont is also of opinion that certain of the Carboniferous Limestones of Belgium (*e. g.* the Limestone of Waulsort) are composed of organisms related to the Stromatoporoids. For these organisms, or for certain of them, the author proposes the generic names of *Stromatactis*, *Stromatocus*, and *Ptylostroma;* but the distinguishing characters of these genera are not given. M. Dupont has been so good as to furnish me with specimens of *Stromatactis*, but I have not been able to recognise in these any characters which would lead me to suppose that they could be placed in the group of the Stromatoporoids.

In 1882, Mr. S. A. Miller described a Stromatoporoid from the Cincinnati group under the name of *Stromatocerium richmondense* ('Journ. Cincinnati Soc. Nat. Hist.,' vol. v). This paper I have not seen.

In 1883, Prof. Ferdinand Roemer published the second part of the text of his great work, the 'Lethæa Palæozoica,' the plates for this having appeared in 1876. In this work the Stromatoporoids are placed among the Hydrozoa, and an account of their general characters and structure is given. The author maintains most of the distinctive views which he had previously published with regard to these organisms. He regards the surface as invariably destitute of larger apertures of every kind, which is certainly not the case in various species in which "astrorhizæ" are well developed, many such having well-marked openings in the centre of the astrorhizæ. The composition of the horizontal "laminæ," out of horizontal anastomosing processes, which leave minute openings between them, is also not recognised by the author, though readily capable of demonstration in well-preserved examples. The "radial pillars" are looked upon as being invariably solid—a view which has been generally held, but which is certainly by no means always correct. The lower surface is rightly stated to be usually covered by a thin, concentrically-wrinkled epithecal membrane, and not to be cemented down to some foreign body. The "astrorhizæ" are regarded, erroneously, as having no value as a specific character, and the absence of central vertical canals is asserted,

though in certain forms such structures are commonly developed. The author's well-known views upon the nature of *Caunopora*, Phill., are here repeated, and the conclusion is expressed that "die angebliche Gattung begreift Stromatoporen die von röhrenförmigen, gewöhnlich zur Gattung *Aulopora* gehörenden, fremdartigen Körpern durchwachsen sind." The genus *Labechia*, E. and H., is placed among the Stromatoporoids, where it properly belongs; and the *Stromatopora dentata* of von Rosen, from the Silurian Rocks of Oesel, is referred to this genus. Lastly, with regard to the species of *Stromatopora* described by Prof. Roemer, it will be better to defer any points which may need discussion till a later period.

In 1883, Herr Eugen Schulz published a very interesting and valuable memoir on the Devonian Limestones of Hillesheim in the Eifel ("Die Eifelkalkmulde von Hillesheim, nebst einem palæontologischen Anhang," 'Jahrg. d. königl. preuss. geol. Landesanstalt für 1882;' Berlin, 1883). The author draws attention to the existence of a well-marked horizon in the Eifel Limestone of the Hillesheim basin, which is characterised by the presence of vast quantities of the singular organisms which Phillips described from the Devonian formation of Devonshire under the name of *Caunopora ramosa*. Herr Schulz points out that the structure of this fossil, of which he figures thin sections, is quite different to that of *Caunopora*, whether we regard the latter as a veritable organism or not. He therefore proposes the new genus *Amphipora* for the reception of this peculiar form.

In 1884, Mr. Carter published a paper under the title 'Note on the Assumed Relationship of *Parkeria* to *Stromatopora*, and on a microscopic section of *Stromatopora mammillata*, Fr. Schmidt" (Ann. and Mag. Nat. Hist., ser. 5, vol. xviii, p. 353). In this paper the author supports his previously expressed view that *Parkeria* is a Hydroid, "indirectly connected through *Hydractinia* with *Stromatopora*." He also confirms, from an examination of a thin section of *Stromatopora mammillata*, Fr. Schmidt, the statement of Murie and myself that the skeleton of the Stromatoporoids is "composed of non-spicular, granular, calcareous matter."

Dr. Carl Riemann has recently published some observations on some Stromatoporoids from the Devonian Limestones of Taubenstein, near Wetzlar ("Die Kalke des Taubensteins bei Wetzlar und ihre Fauna;" 'Neues Jahrb. für Min. Geol. und Palæontologie,' Beilage Band, iii, pp. 142—169, Taf. I, 1884). The limestones in question correspond in a general way with the "Stringocephalen-Kalk" of the Eifel, or with the "Brachiopoden-Kalk" of Schulz; and the author notes the occurrence in them of *Stromatopora concentrica*, Goldf., and *Diapora laminata*, Barg. With regard to the latter, Dr. Riemann supports the views of Bargatzky, and rejects the theory of commensalism put forward by Roemer. The grounds which have led him to take this view are briefly as follows.

(1) *Aulopora* does not appear to occur at Taubenstein, although *Diapora* is present.

(2) The tubes of *Diapora laminata* are much smaller in their diameter than are the tubes of *Aulopora repens*, the common Devonian species of *Aulopora*.

(3) It is very unlikely that any organism should be able to stretch its power of accommodating itself to changes of environment to the extent demanded by Roemer's theory of the commensalism of *Caunopora*. It is known from various observations, including those of Roemer himself ('Leth. Pal.,' p. 519), that each corallite of *Aulopora* ceases to grow so soon as it has begun to throw out buds, remaining thereafter completely stationary, and no longer extending itself vertically. In the case of *Caunopora*, if we admit the correctness of Roemer's views, we should have to suppose that, long after the corallites of *Aulopora* have thrown out buds and had therefore become stationary, they are capable of beginning an entirely new process of growth, as a consequence of entirely changed conditions of life. It would be difficult, however, to point to an analogy to this among recent organisms. So far as we can judge from what we observe at present, the power of accommodation to changes of environment is only possessed by organisms, to any marked extent at any rate, while they are in a state of active growth. On the other hand, when the organism has reached its full limits of growth and has become stationary, its power of accommodation is greatly restricted, and it rapidly perishes if subjected to conditions unsuitable for its life.

Still more recently, Prof. J. W. Spencer has described some Stromatoporoids from the Niagara formation of North America ('Bulletin of the Museum of the University of the State of Missouri,' vol. i, No. 1, pp. 43—52, 1884). The following are described as new species, *Caunopora Walkeri*, *C. mirabilis*, *Cœnostroma ristigouchense*, *C. botryoideun*, and *Dictyostroma reticulatum*.

Lastly, some Stromatoporoids have been described by Dr. Friedrich Maurer in an extensive and valuable memoir on the fossils of the Devonian rocks of the neighbourhood of Giessen ("Die Fauna der Kalke von Waldgirmes bei Giessen," 'Abhandl. der Grossh. Hess. geolog. Landesanstalt zu Darmstadt,' 1885). Dr. Maurer has had the great kindness to send me specimens of most of the forms which he has described, of which I have prepared thin sections; but all the specimens are in an unsatisfactory state of preservation, some being dolomitised, while others are highly crystallised or distorted by pressure. The form which Maurer has described and figured as *Stromatopora concentrica*, Goldf., is (like the form so named by most previous writers) an *Actinostroma*, and appears to be referable to *A. verrucosum*, Goldf., sp. The form identified as *Stromatopora Beuthii*, Barg., is the *S.* (*Caunopora*) *Hüpschii*, Barg., in its normal condition, *i.e. without* any "Caunopora-tubes." On the other hand, *S. indubia*, Maur., is the *S.* (*Caunopora*) *Hüpschii*, Barg., *with* numerous "Caunopora-tubes," and greatly distorted and altered by intense pressure. The species described by Maurer under the name of *S. turgicolumnata* is identical with the form which I understand (from

the specimens sent to me by Bargatzky) to be *Stromatopora Beuthii*, Barg. I should also be disposed to think that the form named *Caunopora placenta*, Phill., is really identical with *S. Beuthii*, Barg., but the fragment sent me by Dr. Maurer is much crystallised and altered, and I should not like to be positive on this point. *Stromatopora maculosa*, Maur., is seemingly a true *Stromatopora*, and is related to *S. Beuthii*, Barg., or to *S. Hüpschii*, Barg., standing apparently very near to the latter; but in this case also the state of preservation is very bad. *S. hainensis*, Maur., I have not seen, and I am not able, therefore, to give any personal opinion as to its relationships; but it may perhaps be compared with the form which I have named *Stromatoporella eifeliensis*. Lastly, it may be mentioned that Dr. Maurer excludes from *Caunopora* all those examples in which there exist imbedded tubes with definite walls, and having horizontal connecting-tubes. Of all such examples he takes Roemer's view, namely that they are the result of the commensalism of a Coral with a Stromatoporoid. He therefore understands by *Caunopora* something quite different to what has been usually understood by this name.

II. GENERAL STRUCTURE OF THE SKELETON OF THE STROMATOPOROIDS.

1. General Form and Mode of Growth.

As regards their general form, the Stromatoporoids present themselves under the most varied aspects, while the mode of growth, though less variable, is also not absolutely constant even among the individuals of a single species. As a general rule, however, each species has a more or less highly characteristic form and mode of growth, from which it only departs when subjected to changes in its conditions of existence. The *typical* form of the skeleton of the Stromatoporoids is that of a hemispherical mass or a flattened expansion, attached by a narrow peduncle, or directly, to some foreign body, but having the under surface covered by a concentrically wrinkled imperforate epitheca, while the apertures for the emission of the polypites are carried upon the upper surface. In form and mode of growth, therefore, the majority of the Stromatoporoids may be, with complete accuracy, compared with the massive or laminated species of *Favosites*, *Pachypora*, *Alveolites*, or *Michelinia*. In a large number of species (such as *Labechia conferta*, E. and H., *Stromatoporella granulata*, Nich., *Clathrodictyon striatellum*, D'Orb., *C. fastigiatum*, Nich., *Stromatopora discoidea*, Lonsd., &c.), the form of the

cœnosteum is almost always that of a thicker or thinner laminar expansion (Pl. III, fig. 7), often of large size, epithecate below, and attached by a narrow basal peduncle. In many other forms (such as *Stromatopora concentrica*, Goldf., *S. typica*, Rosen, and *Actinostroma clathratum*, Nich.) the skeleton is generally of a more massive character, mostly hemispherical or subspherical, the epithecate basal region being reduced in size as compared with the bulk of the organism. Not uncommonly in these more massive species the base is deeply concave, even in very large specimens, and it is sometimes difficult to imagine that the fossil could have been otherwise than quite free.

All the above-mentioned types of Stromatoporoids are occasionally liable to have their surface of attachment extended laterally, so as to suit the particular foreign body to which they may have been originally attached. Hence specimens may be met with in which the colony has been fixed by the greater part, or even the whole, of the lower surface. All of them also are liable to envelope other organisms which may happen to have attached themselves to their surface or to have grown up alongside of them. Hence it is common to meet with specimens which have grown round, or more or less completely enveloped, colonies of *Favosites*, *Alveolites*, *Syringoporæ*, various Rugose Corals, Orthoceratites, Lamellibranchs, or Gasteropods. It is also common to find that specimens of the Stromatoporoids support upon their surface colonies of *Aulopora*, *Favosites*, *Alveolites*, *Thecia*, &c.; these latter, in turn, occasionally supporting a second colony of the same or of some other species of Stromatoporoid. It is, finally, a common thing to find that in some particular locality the Stromatoporoids are particularly liable to grow round and envelope foreign organisms in the way above mentioned, whereas in other localities the same species may be found to manifest very little of this tendency. Thus, in the quarries in the Devonian Limestone of the Schlade-Thal, near Paffrath, the Stromatoporoids seem to have grown round and encrusted almost all the other fossils which occur in the rock; whereas in the Devonian Limestones in the Eifel the same species (such as *Actinostroma clathratum*, Nich.) are almost always massive and independent. This difference in different localities doubtless depends upon the fact that the local conditions, as to depth of water and the like, were not the same in the two areas, and that these organisms accommodated themselves to the particular environment in which they lived.

It is also to be borne in mind that the peculiarities above noted with regard to the mode of growth of the Stromatoporoids are by no means special to these organisms. Thus it is quite a common thing for the massive or laminar species of *Favosites* or *Alveolites* to attach themselves to foreign bodies, or to surround such extraneous organisms, or to have parasitic colonies growing upon their surface. In neither case do the observed phenomena lend any support to the view that the

Stromatoporoid or the Coral was an habitually "encrusting" organism, such as we see in the recent *Hydractinia.*

While the majority of the Stromatoporoids have the under surface largely free and covered by an epitheca, there are, however, other forms which have normally a different mode of growth. Thus certain forms are ordinarily ramose or dendroid, resembling in this respect the ramose species of *Pachypora* or *Alveolites.* This is the case, for example, with *Amphipora ramosa*, Phill., and *Stachyodes verticillata*, M'Coy (Plate VIII, fig. 9).

Lastly, there are species of Stromatoporoids in which the mode of growth is *habitually* an "encrusting" one. Thus, there occurs in the Eifler-Kalk of Gerolstein a Stromatoporoid with remarkably large astrorhizæ, which usually forms thin crusts, attached by their entire lower surface to the summit of expanded specimens of *Heliolites porosa*, Goldf., *Alveolites suborbicularis*, Lam., and *Chætetes stromatoporoides*, Roemer.[1] This species, however, though usually encrusting, is not invariably so, for I have collected examples of considerable thickness in which the under surface has been furnished with an epitheca. Some of the forms which were included by Goldfuss under the name of *Stromatopora polymorpha* (*e.g. S. curiosa*, Barg.) appear also to usually form crusts attached to the exterior of corals. This is, further, the case with the form which I described from the Devonian Rocks of North America under the name of *Stromatopora nulliporoides* ('Second Rep. on the Palæontology of the Province of Ontario,' p. 78).

Upon the whole, however, it may be unhesitatingly asserted that an "encrusting" mode of growth, such as we see in the recent *Hydractinia*, is very unusual among the Stromatoporoids, but that they mostly grow after a fashion very similar to what is seen in the majority of the species of *Favosites* and *Alveolites.*

2. Chemical Composition and Mode of Preservation.

The Stromatoporoids occur for the most part in limestones, but they are occasionally found in argillaceous sediments. They may be regarded, in fact, as having played quite as important a part in the formation of the older Palæozoic Limestones as even the Corals themselves, whole beds of Silurian and Devonian Limestone being often essentially made up of the remains of these organisms.

The majority of specimens of the Stromatoporoids are composed of carbonate of lime, but it is not unusual, in certain beds, to find specimens in which the skeleton is siliceous. This fact has led some observers to conjecture that the

[1] This curious Stromatoporoid (Pl. IV, fig. 2) is very abundant at the Auberg, near Gerolstein. It has been wrongly identified by Roemer with *Stromatopora concentrica*, Goldf. ('Lethæa Palæozoica,' p. 460). It is really a species of *Stromatoporella,* and may be provisionally termed *S. eifeliensis.*

Stromatoporoids possessed a primitively siliceous skeleton, and that all calcareous specimens owe their present constitution to the fact that the original silica of the skeleton has been replaced by carbonate of lime. This conjecture has been fully discussed by Dr. Murie and myself ('Journ. Linn. Soc.,' vol. xiv, p. 197), and the evidence against its correctness is so overwhelming that it is unnecessary to enter again into the question here. It is sufficient to point out that adequate proof of the fact that the skeleton of the Stromatoporoids was primitively calcareous in its constitution is to be obtained from the following considerations: Firstly, in all those Silurian and Devonian Limestones in which the Corals, Brachiopods, and other fossils are normally calcareous or non-silicified, the Stromatoporoids are also calcareous. Secondly, in all those deposits in which we meet commonly with Stromatoporoids having a siliceous skeleton, we find the Corals, Brachiopods, and associated fossils to be mostly or wholly silicified. Thirdly, the skeleton of the Stromatoporoids is composed, normally, of *granular* carbonate of lime, whereas if it had been originally composed of silica and had been replaced by carbonate of lime at some period subsequent to fossilisation, it ought to consist of *crystalline* carbonate of lime.

As I shall point out immediately, there *are* cases among the Stromatoporoids where the original skeleton has been replaced by calcite; but these lend no support to the view that the skeleton was primitively siliceous, and seem really to point to the fact that the skeleton was composed of *arragonite*, rather than of ordinary carbonate of lime.

There are, in fact, three principal modes of preservation under which specimens of the Stromatoporoids present themselves. In the first group of specimens, comprising by far the larger number of ordinary examples, the actual skeleton has been preserved more or less unchanged, and all the cavities of the skeleton have been infiltrated with transparent calcite. In such specimens (Plate I, fig. 1) the skeleton is readily distinguished from the calcareous infilling of the chambers, in thin sections, by its brown colour and granular or cloudy, non-crystalline texture. In certain cases, however, the skeleton has undergone a partial secondary crystallisation, and is then only distinguishable from the calcite-matrix by its darker colour and less complete crystallisation. Specimens of this kind occur more commonly in dolomitic limestones than in ordinary limestones, though sometimes seen in the latter.

In a second group of specimens, more or less complete silicification has taken place. In some examples, the actual skeleton has remained more or less completely calcareous, while the cavities of the skeleton have been filled in with silica. In other cases, not only is the infilling of the chambers siliceous, but the skeleton itself has been replaced by silica. In other cases, again, the porous skeleton of the Stromatoporoid has, to begin with, been infiltrated with water holding mineral

substances in solution, the result being the formation of a thin layer of crystals of carbonate of lime or of silica in the interior of the chambers ; and then at a later stage all the remaining cavities have been filled up with transparent silica (Plate I, fig. 2).

In a third group of specimens, of comparatively rare occurrence, a still more remarkable series of changes has taken place. The specimens in question are preserved in limestones or in argillaceous deposits, and the first change to which they were subjected consisted in the complete infiltration of the porous skeleton, not with transparent calcite as in the first group of cases, but with fine calcareous mud or minutely levigated argillaceous sediment. When in this condition, we must suppose that the calcareous skeleton was more readily soluble in percolating water than the calcareous or argillaceous mud filling the interstices of the fossil—this greater solubility being due either to the fact that the skeleton consisted of arragonite, or perhaps merely to its being impregnated with organic matter. The next step in the process, therefore, consisted in the gradual dissolution of the skeleton and its replacement by *crystalline carbonate of lime*, the infilling of the chambers remaining in the meanwhile unaltered. Hence, thin sections of such specimens show a precisely reversed condition of matters to what we observe in ordinary non-silicified examples. Instead of seeing the dark-coloured skeletal framework filled in with transparent calcite, we now see the entire skeleton represented by clear calcite, while the chambers, pores, and canal-system of the fossil are represented by comparatively opaque calcareous mud or fine argillaceous sediment.

It is only comparatively recently that I have been led to recognise this very peculiar mode of preservation as occurring among the Stromatoporoids, and that I have been able to interpret the very puzzling phenomena to which it gives rise. It occurs, among British specimens, most commonly in certain of the Stromatoporoids of the Devonian Limestones of Devonshire, and especially in a form (*S. dartingtonensis*, Carter) with exceedingly large astrorhizæ.[1] I have figured (Plate IV, fig. 1) a portion of a tangential section of this form, in this state of preservation, showing the appearances which it presents when the canal-system and chambers are in this way filled up with comparatively opaque calcareous mud. For comparison with this, I have also figured the same section, as it would appear supposing it to have been preserved in the ordinary manner, viz. with the skeleton comparatively opaque and the canal-system and chambers filled in with transparent calcite (see Plate IV, fig. 1, *a*).

A still more easily recognisable case of the same mode of preservation is presented by a specimen (in my collection) of an apparently undescribed species of *Labechia* from the Cincinnati group of Ohio, which I may provisionally term *L.*

[1] The form in question has been spoken of by Mr. Carter as *Stromatopora elegans*, Rosen, but it is really only a peculiar condition of *S. Dartingtonensis*, Carter, and is quite distinct from Rosen's species.

ohioensis[1]. In this specimen all the interspaces of the fossil have been filled in with a fine-grained greenish calcareous mud, the skeleton having been subsequently dissolved out and then replaced, more or less completely, with transparent calcite (Pl. II, figs. 1 and 2). Another case of the same mode of preservation is presented by the curious fossil described by Dr. Murie and myself from the Trenton Limestone of Canada, under the name of *Stromatocerium canadense* ('Journ. Linn. Soc.,' p. 223, Pl. iii, figs. 9 and 10). At the time we described this fossil, we had not observed any cases of the mode of preservation now in question, and we therefore naturally regarded the portions of the fossil which were composed of calcite as being the canals and chambers of the organism, and the dense and opaque portions as being the skeleton. In reality, however, the chambers have been filled with dense calcareous mud, and the skeleton has been replaced by calcite (Pl. II, figs. 3—5). *Stromatocerium canadense*, Nich. and Murie, when viewed in this light, is therefore no longer the anomalous form that it appeared to be, but is readily recognised as a species of *Labechia*, which, being apparently distinct from previously described forms, must stand as *L. canadensis*, Nich. and Murie.

3. Minute Structure of the Stromatoporoids.

All palæontologists probably will readily admit that the study of the Stromatoporoids can only be prosecuted, with any certainty, by means of properly prepared thin sections, which can be examined under the microscope by means of transmitted light. In mode of growth, in their general form, and in their merely superficial characteristics, many Stromatoporoids present a remarkable similarity; and hence many observers have been led to regard the majority of these organisms as being nothing more than variations of a common type, their differences being supposed to be due to local conditions, or to the adaptations rendered necessary in different individuals by differences in their environment. Thus, even at the present day, so distinguished and acute an investigator as Professor Ferd. Roemer is inclined to regard the greater number of the Devonian Stromatoporoids of Germany as mere variations of the *Stromatopora concentrica* of Goldfuss, and a considerable number of the Upper-Silurian forms as variations of *S. striatella*, D'Orb.

My own experience, based on a study of many hundreds of microscopic slides, has led me to the conclusion that the minute internal structure of the skeleton of the Stromatoporoids shows very remarkable and constant differences, even in types which in external aspect are not very dissimilar; that in properly prepared sections

[1] So far as I am aware, no species of *Labechia* has been hitherto recorded from the Silurian Rocks of North America. *Labechia ohioensis* differs from *L. conferta*, Lonsd., in the greater delicacy of the radial pillars, these structures often appearing to be angulated rather than round, while the vesicles of the interstitial tissue are much more minute than in the latter species.

these differences can be recognised with absolute certainty, provided the internal structure has not been destroyed in the process of fossilisation; and that both in consistency and in amount they are perfectly adequate for the discrimination of the different species, or for the establishment of generic distinctions. Moreover, when once the peculiarities of the microscopic structure have been fully recognised, it is usually quite easy to correlate these with small and otherwise hardly recognisable external characteristics, so that it becomes, in general, a comparatively light matter to determine the position of a given specimen by a mere macroscopic examination. I do not mean to assert that the generic divisions of the Stromatoporoids are all rigidly marked off by their minute structure, for there are types, of an inosculant character, which it is difficult to place definitely in one genus rather than in another. Nor do I mean to assert that one does not meet with specimens which can only with difficulty and uncertainty be determined even with the help of microscopic sections. I do mean to assert, however, that the minute microscopic structure of the skeleton of the Stromatoporoids may be relied upon in the determination of species or genera, to just the same extent, with just as much certainty, and under precisely the same limitations, as in the case of the Corals or the Polyzoa.

There is, however, a special and exceptional difficulty in the case of the Stromatoporoids in the preparation of thin sections, which should not be passed over wholly without remark. As will be seen immediately, the skeleton of the Stromatoporoids consists essentially of two sets of elements, one radial and the other tangential, as regards the whole specimen, and therefore in the main intersecting each other at right angles. Hence, two sets of sections must in all cases be prepared, viz. one section parallel with the radial (or vertical) elements of the skeleton, and one at right angles to this, parallel with the tangential (or horizontal) elements of the skeleton. If the two component elements of the skeleton were rectilinear, and cut each other accurately at right angles, it would be an easy matter to prepare such sections. As a matter of fact, however, the vertical or radial elements of the skeleton are usually flexuous, and the tangential or concentric elements are invariably more or less curved; so that it is a matter of more or less difficulty to prepare slides which shall be accurately parallel to either of these sets of elements. It is, however, absolutely necessary to secure approximate parallelism to the constituent elements of the skeleton, if the sections are to yield reliable information. A very slight obliquity—especially in vertical sections—causes a distortion of the structure, which may be recognised and allowed for by the experienced observer, but which is exceedingly likely to mislead anyone who has not examined a large series of specimens. For the same reason, the beautiful polished sections prepared by lapidaries are in many cases of comparatively little value for working purposes, as they are cut at all angles of obliquity to the

component parts of the skeleton, and thus yield results which may be easily misleading.

Moreover, under certain circumstances, which are not easy to explain, the skeleton of the Stromatoporoids is liable to undergo a more or less complete secondary crystallisation, by which the internal structure is greatly obscured or, it may be, completely obliterated. This is seen in many of the specimens from the Devonian Limestones of Devonshire, and particularly in many of those found in the rolled limestone pebbles of the Triassic conglomerates of South Devon. In these cases, it would seem probable that the crystallisation is largely connected with mechanical causes, as it is almost always accompanied with a greater or smaller amount of distortion of the skeletal framework. In other cases, however, the crystallisation is the result of an internal rearrangement of the particles of which the skeleton is composed, the general form of the skeleton remaining unchanged, while the surface and the epitheca may be beautifully preserved. This is commonly seen in the Stromatoporoids of the Wenlock Limestone of Gotland and of Esthonia, and, more rarely, in specimens from the Wenlock Limestone of Britain.

In the following general account of the structure of the skeleton of the Stromatoporoids, it will not be possible to take any one single type as illustrative of the main facts to be considered, as there exist very wide variations within the limits of the group, as here understood. We shall find, however, that these variations may, on the whole, be reduced to one or other of two leading types of structure. In one series of forms, of which the true *Stromatopora concentrica* of Goldfuss is the type, the skeleton is of what may be called the "Milleporoid" type, having what Mr. Carter has designated as a "curvilinear" structure. In the other great series of forms, typified by *Actinostroma clathratum*, Nich.,[1] the skeleton is of what may be termed the "Hydractinioid" type, having what Mr. Carter has called the "rectilinear" structure.

The bond of union by which these two groups of forms are linked together, is found in the fact that the calcareous cœnosteum in both groups can be shown to be made up of two sets of elements, one vertical to the surface, and the other parallel with the surface. In the "Milleporoid" series, typified by *Stromatopora*, Goldf., the vertical or "radial" elements are so combined with the horizontal or "concentric" elements as to give rise to a continuously reticulated skeleton, in which the elementary constituents are with difficulty recognisable as distinct structures. On the other hand, in the "Hydractinioid" series, typified by *Actinostroma*, Nich., the "radial" and "concentric" elements of the skeleton remain more or less clearly recognisable as distinct structures, and the skeleton never has the form of a continuous vermiculate reticulation.

[1] It is to be borne in mind, as previously explained, that the form here called *Actinostroma clathratum* is what has hitherto been regarded as being *Stromatapora concentrica*, Goldf., a microscopic examination of the original of the latter having shown that its structure is quite unlike what it was supposed to be.

The one feature which, perhaps more conspicuously than any other, characterises the entire group of the Stromatoporoids, is the constitution of the skeleton, more or less obviously, of superimposed concentric layers. Sometimes, as in *Stromatopora concentrica*, Goldf., the skeleton is composed of concentric strata ("latilaminæ) of considerable thickness (Plate V, figs. 8 and 9). In such cases, the intervals between two of the "latilaminæ" merely mark periodic pauses in the growth of the skeleton, and it is difficult or impossible to recognise any composition of the individual strata out of secondary layers or "laminæ." Each stratum, or "latilamina," is made up of a series of parallel vertical rods ("radial pillars"), which run from the top to the bottom of the stratum, and are united at irregular intervals by oblique or horizontal processes (Plate V, figs. 10 and 15; Plate XI, fig. 18). The intervals between these vertical rods are the tortuous tubular canals in which the zoöids of the colony were lodged, and they are often "tabulate." In other forms the entire skeleton is made up of closely approximated concentric layers, or "laminæ," which may or may not be arranged in thick strata, or "latilaminæ" (Plate I, figs. 9 and 12). The "laminæ" are not in absolute contact, but are separated by narrower or wider interspaces ("interlaminar spaces"). These interspaces are intersected by numerous vertical columns ("radial pillars"), which connect together the laminæ bounding the interspace on both sides, and may run continuously through several interspaces and laminæ. Reduced to its simplest expression, the above may be taken as giving the essential structure of a typical Stromatoporoid; but it will be necessary to discuss the different elements of the skeleton separately and in greater detail, and to consider the more important variations which they exhibit in different types of the group.

(*a*) *The Skeletal Tissue.*—The investigation of the ultimate structure of the skeletal tissue of the Stromatoporoids is a matter of great difficulty, owing to the fact that in many specimens the skeleton has undergone considerable secondary alteration, while probably none retain their original constitution unchanged. There is, in fact, considerable reason for concluding that the skeleton was originally composed of arragonite, and that in almost all, or perhaps all, specimens which have not been silicified, the arragonite has become more or less extensively replaced by calcite. In the case of the Stromatoporoids from the pebbles of Devonian limestone contained in the Triassic conglomerates of Devonshire, the skeleton usually consists, like the matrix, of crystals of calcite, and is chiefly distinguishable from the matrix by its darker colour. Hence, in these specimens little or no advantage can be gained by the preparation of very thin sections, as the reduction of the slide to extreme tenuity renders the skeleton more or less inconspicuous, or even undistinguishable from the surrounding matrix. In specimens which have undergone less alteration during the process of fossilisation, as in most of the examples from the Wenlock Limestone of Britain, the skeleton of certain types (*e. g. Actinostroma*

and *Clathrodictyon*) seems to be composed of exceedingly minute granules of carbonate of lime. In thin sections of such types (Plate I, fig. 1) the skeleton-fibre appears generally to be of a much darker colour than the matrix, and often presents a tolerably uniform cloudy or granular aspect, mostly darkest in the centre, and shading off to a blurred and ill-defined margin. Under high magnifying powers, and in sufficiently thin sections, innumerable minute irregular dark specks, sometimes with a clear centre, may be seen to be disseminated through the fibre. The form of these specks is very irregular, and it is their presence which gives to the fibre its cloudy aspect when examined under low magnifying powers. I am inclined to think that these specks are certainly of the nature of minute vacuities in the fibre, more or less completely filled up with opaque matter, and that they represent the system of minute pores or tubuli which characterise the skeleton-fibre of certain other types. These minute specks are exceedingly well shown in very thin sections of *Labechia conferta*, in which I shall be able to show that the radial pillars have an unquestionable cribriform structure.

In no case has any observer succeeded in detecting anything of the nature of definite *spicules* in the skeleton-fibre of the Stromatoporoids; and this has always been one of the strongest arguments against the reference of these organisms to the Sponges.

There are, however, many Stromatoporoids in which the skeletal tissue has an obviously complex character, the nature of which can not be always fully determined. Thus, in all the species of the genus *Stromatopora*, Goldf., thin sections, taken either tangentially or vertically, exhibit a characteristic dotted or porous structure, the skeleton-fibre being marked with innumerable oval or rounded, clear spaces, surrounded by dark granular tissue (Plate I, figs. 6 and 7). In some cases, as in *S. Carteri*, n. sp., *S. Beuthii*, Barg. (Plate V, figs. 12 and 13), *S. Hüpschii*, Barg. (Fig. 6), and others, this vesicular structure of the fibre is upon such a large scale as to be recognisable with the use of a hand-lens and in merely polished slabs. In most cases thin sections are necessary for its demonstration. In other cases, the structure, though essentially the same as in the forms above mentioned, is more minute. Thus in the common *S. typica*, Rosen, of the Wenlock Limestone, the skeleton-fibre, as seen in thin sections, has a minutely dotted aspect (Plate I, fig. 3), the clear spaces in the fibre being very small, and often replaced by opaque dots. That in all these cases the clear spaces in the fibre are really of the nature of vacuities, filled with transparent calcite, can hardly be doubted; and that these vacuities are of the nature of *vesicles* rather than of *tubes*, would seem certain from the fact that there is no sensible difference in their shape as displayed either in tangential or in vertical sections.

In the species of the genus *Stromatoporella*, Nich., not only is the skeleton-fibre similarly vacuolated, but the cavities in the fibre often assume the character of a

system of minute branching tubuli. Thus, in *Stromatoporella granulata*, Nich., from the Hamilton formation of Canada, in which the skeleton has undergone little change, tangential sections (Plate I, fig. 4) show that the skeleton-fibre is traversed by numerous minute vesicular cavities and elongated or flexuous canaliculi, separated by the ordinary granular tissue of the skeleton. Vertical sections (Plate I, fig. 5) exhibit the same condition of things, the minute channels of the fibre being mostly directed vertically, and leaving a comparatively clear central line in the centre of the fibre. The same structure is still better shown in other species of *Stromatoporella*. Thus in *S. eifeliensis*, Nich. (Plate XI, figs. 1 and 2), both the horizontal laminæ and the radial pillars are seen in really well-preserved examples to be traversed by a central clear space, connected on both sides with a complex system of ramifying canaliculi, which branch out in the substance of the fibre. There seems no reason to doubt that the clear central line above spoken of is really a tube, and that the entire system is one of minute intra-skeletal tubuli filled during life with living matter, similar to what is found in the skeleton of the living *Distichopora* (Plate IV, fig. 4, and Plate IX, fig. 5). A system of precisely similar tubuli is found in an allied species of *Stromatoporella* from the Eifel (Plate XI, figs. 3 and 4). On the other hand, in *S.* (*Diapora*) *laminata*, Barg., the skeleton-fibre has more of a coarsely porous than of a tubulated structure (Plate XI, fig. 10), tangential sections of this species often showing here and there comparatively large-sized clear circular spaces, which seemingly represent the axial canals of the radial pillars.

The cases just considered are alike in the fact that the skeleton-fibre, as seen in thin sections, is opaque and granular, while the pores or tubuli appear as clear spaces in the substance of the fibre. There are cases, however, in which this state of things is reversed. This is seen on a large scale in the genus *Hermatostroma*, in which the skeleton-fibre is composed of clear and transparent carbonate of lime, exhibiting in its interior conspicuous opaque dots and lines. In vertical sections (Plate III, fig. 2) each radial pillar exhibits a dark central axis, while similar but more slender lines run in the interior of the horizontal laminæ. In tangential sections (Plate III, fig. 1) each transversely-divided radial pillar exhibits a central dark dot, from which often radiate delicate dark lines. It is hardly possible that we can here have anything else to deal with than a more or less complicated canal-system in the interior of the skeleton-fibre, the larger divisions of which are now injected with some opaque material, such as oxide of iron.

The same phenomenon on a more minute scale, and in a completely convincing form, is shown by specimens of *Stachyodes verticillata*, M'Coy, sp. In some examples, namely, of this species the skeleton-fibre is traversed by delicate tubuli, which appear in cross sections as transparent dots (Plate XI, fig. 6), and in longitudinal sections as clear lines. In other specimens of the same species no

tubuli are visible, but the skeleton-fibre exhibits in tangential sections numerous dark dots (Plate XI, fig. 5), and in long sections corresponding delicate dark lines. It cannot be doubted that the different appearances presented by different examples of this species depend upon the nature of the material which has served as the infilling of the canal-system of the fibre, the tubuli being in the one case filled with transparent calcite, and in the other with opaque oxide of iron.

There are, however, still other cases in which the appearances presented by the skeleton-fibre are more puzzling, though the phenomena just recounted would seem to afford a key to their true nature. One of the cases in question is that of *Parallelopora ostiolata*, Barg., of which, through the kindness of Professor Schlüter, I have investigated the original specimen. In tangential sections of this singular type (Plate II, fig. 6) the skeleton-fibre is seen to be thick and reticulated, and to be composed of nearly transparent carbonate of lime. Scattered through the transparent fibre, and particularly abundant on its edges, are numerous conspicuous dark dots, of oval, circular, or elongated shape, and of variable size. Some of the dots show a minute ill-defined light centre, but they are mostly quite opaque. In vertical sections of the same these dark dots are seen to be the cut ends of minute rod-like bodies, which are prolonged vertically downwards, running parallel with one another in the substance of the skeleton-fibre (Plate II, fig. 7) in the intervals between the tabulate zoöidal tubes. These rods are dark and opaque, and are connected together at tolerably regular intervals by dark horizontal lines, which constitute a series of horizontal or concentric laminæ. It seems to me that the most probable explanation of the appearances just mentioned is that the dark rod-like bodies in the substance of the skeleton-fibre are really of the nature of delicate tubuli filled up by some opaque material, and that the dark cross lines by which they are connected together represent a system of horizontal tubuli similarly injected. The phenomena previously alluded to as seen in thin sections of *Stachyodes verticillata*, M'Coy, and *Hermatostroma Schlüteri*, Nich., would entirely bear out this view of the subject. Moreover, this explanation is further supported by an examination of one of the other species of *Parallelopora*, viz. *P. Goldfussi*, Barg., of which I have also been able to examine the original specimens. In this form the thick reticulated skeleton-fibre is seen in thin sections to be traversed by numerous comparatively large vacuities or clear spaces (Plate XI, fig. 9), which are bounded by dark tissue. These were regarded by Bargatzky ('Die Stromatoporen des rheinischen Devons,' figs. 10 and 11) as being so many vertical "cœnenchymal tubes." In one sense this view is correct, since these tubes were doubtless filled with organic matter during life; but the "cœnenchymal canals" of this and other similar forms are, strictly speaking, the much larger canals which place the different zoöids in communication. The tubuli of *P. Goldfussi*, Barg., do not, however, differ essentially from the still more

minute vesicles and tubuli which are found in the skeleton-fibre of *Stromatopora*, *Stromatoporella*, and *Stachyodes*, and they are not so regular nor so continuous as they are shown to be in Bargatzky's figures, while they have much thicker walls. Moreover, if we examine thin sections of other specimens of what I believe to be the same species (which is very probably the same as the *Stromatopora capitata* of Goldfuss) we find that the skeleton-fibre exhibits in thin tangential sections numerous large, dark, rounded dots, which in longitudinal sections are seen to be really the cut ends of dark rod-like bodies, the fibre itself being clear and transparent (Plate XI, figs. 7 and 8). I take it, therefore, that in this case also we have really to deal with a system of vertical canals, which run in the skeleton-fibre, and are connected at intervals by cross branches, and that the different appearances presented by different specimens result from the infiltration of these canals in the one set of examples with calcite, and in the other set with oxide of iron.

(*b*) *The Radial Pillars and Concentric Laminæ.*—If such a Stromatoporoid as *Actinostroma clathratum* be examined, the skeleton is seen to consist of two principal sets of structures, one "radial" or vertical, the other "concentric" or horizontal. These may be termed respectively the "radial pillars" and the "concentric laminæ" or "horizontal laminæ" (Plate I, figs. 9 and 12). These may be exceedingly distinct, or they may be so far blended together as to be hardly or not at all recognisable as separate structures, so that it is almost a matter of necessity to deal with these two constituents of the skeleton in conjunction.

In most Stromatoporoids the "concentric laminæ" are the most conspicuous structures, as giving rise to the characteristic foliated structure of most of the fossils of this group. The skeleton, in fact, will in most cases split more or less readily in a direction parallel with these laminæ, and therefore tangential to the general surface; whereas it has little or no natural tendency to fracture in directions at right angles to the surface, *i.e.* parallel to the radial pillars. The laminæ are never strictly "horizontal," but are more or less undulated or curved, the entire skeleton being thus more or less obviously formed of concentrically disposed layers. In certain forms, moreover, (*e.g. Actinostroma verrucosum*, Goldf.) the laminæ are only partially concentric as regards the general surface, but are concentrically arranged with regard to a number of points or lines of growth.

Successive laminæ are separated by interspaces which are usually much wider than the laminæ themselves, and which are termed the "interlaminar spaces." These spaces are most conspicuous in forms such as *Actinostroma* and *Clathrodictyon* (Plate I, figs. 9 and 1). Even in these cases the interlaminar spaces are not absolutely continuous, but are intersected at right angles by the "radial pillars," which spring from the lamina which bounds the interspace inferiorly and extend upwards, sometimes falling short of the upper bounding lamina, sometimes reaching it and sometimes being continued onwards through many successive

laminæ and interlaminar spaces. On the other hand, in the genus *Stromatopora*, Goldf., itself, and in some other forms, the interlaminar spaces become reduced to rows of irregular chamberlets, or may even be almost obsolete (Plate V, fig. 15, and Plate VII, fig. 2).

Growth of the skeleton in the Stromatoporoids is effected by the upward extension of the radial pillars, and the production of successive concentric laminæ from their apices. In many Stromatoporoids there occurred, in addition, periodic pauses in the upward growth of the pillars and in the production of new laminæ, giving rise to a sort of major stratification of the skeleton. That is to say, the skeleton is now not only composed of successive "concentric laminæ," but these in turn are arranged in concentric strata of comparatively considerable thickness. Successive strata may be in contact, or may be separated by incomplete intervals, which are sometimes partially filled up with the matrix (Plate V, figs. 8 and 9). In any case, the fossil splits more easily along the lines of division between successive strata than elsewhere. I shall apply the term of "latilaminæ" to these thick strata, which result from an intermittent method of growth. They are very conspicuous in some types of *Actinostroma* (*e. g. A. clathratum*, Nich.); but they are exhibited in perfection in many species of the genus *Stromatopora*, Goldf., and particularly in the type-species *S. concentrica*, Goldf. (Plate XI, fig. 15). There, is, moreover, this difference between the "latilaminæ" in the cases just mentioned. In *Actinostroma*, namely, each "latilamina" is made up of a series of subordinate "concentric laminæ;" whereas in the true *Stromatoporæ* the proper "concentric laminæ" can not be said to have any recognisable existence, or are, at any rate, imperfectly developed; so that the "latilaminæ" have no tendency to split along a subordinate series of concentric layers.

As regards the *general* arrangement of the "radial pillars" and "concentric laminæ," the genera *Stromatopora*, Goldf., and *Actinostroma*, Nich., may be taken respectively as types of the two principal sections of the Stromatoporoids, namely, the Milleporoid and the Hydractinioid sections. In the genus *Stromatopora*, Goldf., the radial pillars and concentric laminæ are completely amalgamated with one another, and are hardly recognisable, as a rule, as distinct structures. Hence, in tangential sections of such forms (Plate V, figs. 14 and 15, and Plate XI, fig. 16) the skeleton is seen to be a continuous reticulation, resembling that of *Millepora*. In vertical sections of the same, the radial pillars can usually be recognised to be present, but they are thick, irregular, and flexuous, and the "concentric laminæ" are only represented by irregular lateral outgrowths, which spring from the pillars and unite them into a continuous framework (Plate V, figs. 15 and 17, and Plate XI, fig. 18). In certain of the *Stromatoporæ*, however, though the skeleton has the completely reticulate structure which characterises the genus, the "radial pillars," nevertheless, persist as distinct structures. Thus, in tangential sections

of *S. Beuthii*, Barg., the cut ends of the radial pillars can be recognised in the interior of the general reticulation (Plate V, fig. 12), and their existence can also be made out in vertical sections (Plate V, fig. 13). This fact—and there are other similar ones in other species—show that the striking dissimilarity between the true *Stromatoporæ* and the *Actinostromata* is more apparent than real, and that similar structural elements are really present in both.

On the other hand, in the "Hydractinioid" section of the Stromatoporoids, represented by forms such as *Actinostroma clathratum*, Nich. (the *Stromatopora concentrica* of authors), the radial pillars and concentric laminæ are present as distinct, though closely connected structures. Thus, in vertical sections of *A. clathratum* (Plate I, figs. 9 and 12) we observe a series of longer or shorter parallel vertical rods, placed at tolerably equal distances, and connected at regular intervals by a series of parallel horizontal laminæ. The vertical rods, or "radial pillars," appear to vary much in length, but this is really due to the fact that the section never passes along the plane of any one rod for more than a very limited distance. In reality, the radial pillars are in this species continuous for very considerable distances, running persistently through twenty or thirty, or more, successive laminæ and interlaminar spaces. Indeed, as this species is one which grows with "latilaminæ," it is probable that most of the radial pillars run continuously from the lower surface of a latilamina to the upper surface of the same. If the section under examination be at all oblique, or inclined to the axes of the radial pillars, then the pillars appear to run only from one lamina to the next, instead of showing their true "continuous" character.

If we next look at a tangential, or horizontal, section of *Actinostroma clathratum* (Plate I, figs. 8 and 11), we necessarily see the transversely-divided ends of the radial pillars, in the form of either rounded or stellate dots, placed at tolerably regular intervals. The precise form in which the cut ends of the radial pillars present themselves depends upon the precise level at which they happen to have been divided in the section examined. The radial pillars, in fact, give out at regular intervals verticils of horizontal connecting-processes or "arms," which join with one another to form a more or less complete network, as they are given out at successive corresponding levels by all the pillars. Each successive "concentric lamina" is thus formed by the fusion of the ends of the connecting-processes or "arms" of the radial pillars at a given level. Hence, if the line of the section passes along the plane of one of the concentric laminæ, then the cut ends of the radial pillars have a stellate form (Plate I, fig. 10); the "arms" forming by their union an angular meshwork not unlike the skeletal framework of a "hexactinellid" sponge. If, on the other hand, the line of the section should correspond with one of the interlaminar spaces, then the cut ends of the radial pillars appear to be simply rounded or oval (Plate I, fig. 13). Owing to the undu-

lating form of the fossil, all obtainable tangential sections, as a matter of fact, run partly through the horizontal laminæ, and partly through the interlaminar spaces.

As regards the "concentric laminæ" of *Actinostroma clathratum*, Nich., and of similar forms, very different appearances are presented by tangential and vertical sections respectively. The former show us, as above pointed out, that the concentric laminæ are really formed by the inosculation and fusion of the radiating processes, or "arms," thrown out by the radial pillars at definite and corresponding intervals. It follows from this that the concentric laminæ are not, strictly speaking, "laminæ" at all, but that they are really only a closer or looser reticulation of calcareous fibres, penetrated by more or less numerous pores of various sizes and shapes (Fig. 1, A). Hence, if we examine the surface of any concentric lamina in *Actino-*

Fig. 1.

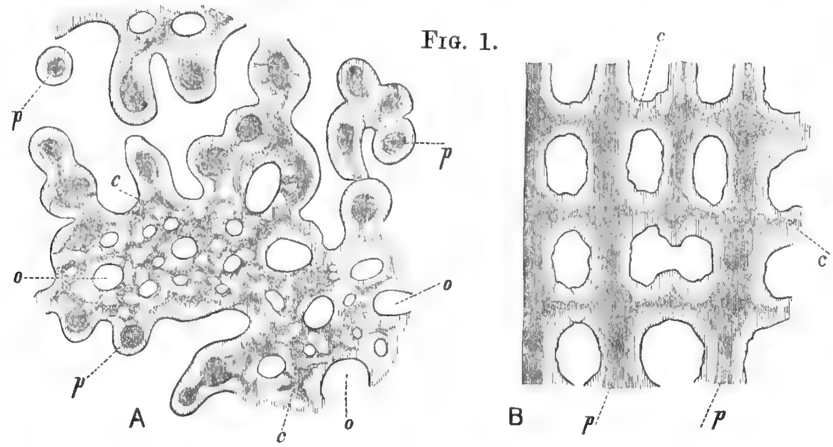


Fig. 1.—Thin sections of *Hermatostroma Schlüteri*, Nich. A. Tangential section. B. Vertical section. Enlarged twenty-four times. The tangential section passes along the plane of one of the concentric laminæ, and shows the cut ends of the radial pillars with their axial canals (*p p*), the extension of the canals into the laminæ (*c c*), and the pores formed by the inosculation of the horizontal processes or "arms" (*o o*). The vertical section shows the axial canals of the pillars (*p p*) and the extensions of these canals horizontally into the concentric laminæ (*c c*). Devonian, Herborn, near Paffrath.[1]

stroma clathratum, either by looking at the actual surface or by studying the plane of a concentric fracture, or if we take a properly prepared tangential section, we can observe numerous minute pores passing through the lamina, and placing the interlaminar space below the lamina in direct communication with the interlaminar space above the same. These pores are most readily recognised as being truly "pores," if we have under observation such forms as any of the true *Stromatoporæ*, in which the general skeleton is reticulated and continuous, but we cannot refuse this name to the wider, more open, and more irregular meshes formed by the union of the horizontal "arms" in the typical *Actinostromata* (Plate I, figs. 8 and 10).

[1] I take this opportunity of expressing my sense of the very admirable manner in which Mr. Charles Ferrier, F.L.S., has engraved on the wood such highly trying subjects as the thin sections figured in this work.

Most Stromatoporoids show, in one form or another, similar openings in the concentric laminæ, and we can hardly doubt that they served for the passage of stolons of the cœnosarc, and, in the last formed lamina, for the emission of zoöids.

In spite of the fact that the concentric laminæ are thus porous, they necessarily present themselves in thin *vertical* sections as continuous horizontal lines, since the interlacing "arms," out of which they are formed, are placed at corresponding levels (Plate I figs. 9 and 12).

(*c*) *Variations in the Structure of the Radial Pillars and Concentric Laminæ.*—The above is, in brief, the general structure of the skeleton in the two great sections of Stromatoporoids represented respectively by *Stromatopora*, Goldf., and *Actinostroma*, Nich. There are, however, numerous more or less striking deviations from this type which require consideration. Most of these will be best discussed in connection with the descriptions of the genera and species. It will be sufficient, therefore, here merely to deal briefly with certain points of special structural importance.

Fig. 2.

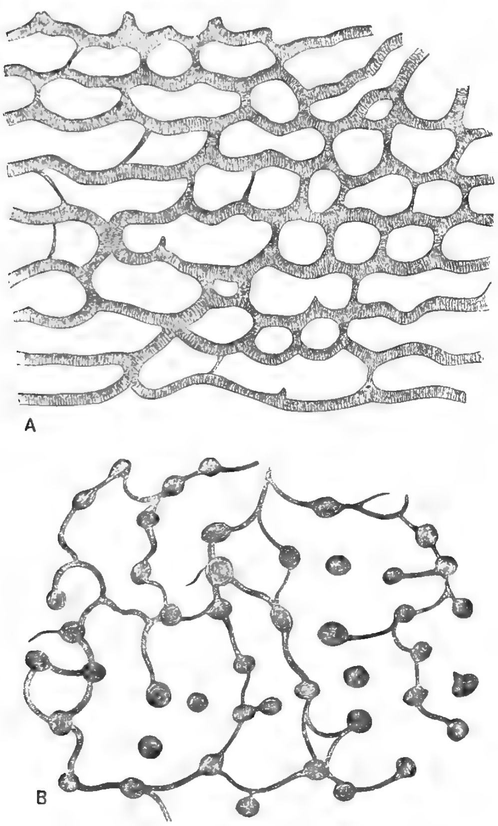


Fig. 2.—A. Vertical section of *Clathrodictyon cellulosum*, Nich. and Mur., enlarged twelve times. B. Tangential section of the same, similarly enlarged. Corniferous Limestone, Wainfleet, Ontario.

Fig. 3.

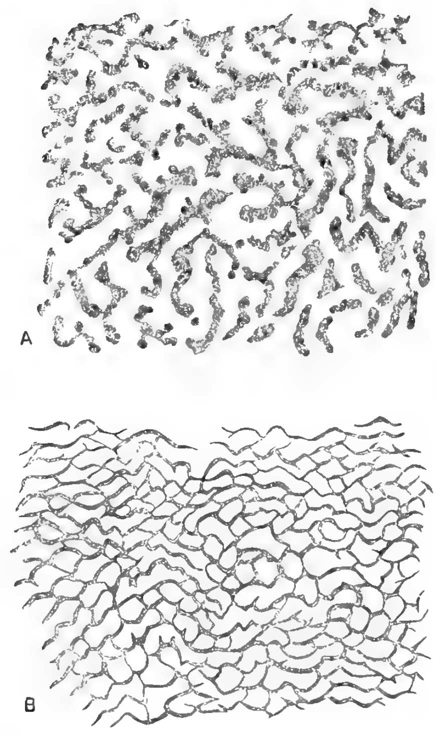


Fig. 3.—A. Tangential section of *Clathrodictyon fastigiatum*, n. sp., enlarged twelve times. B. Vertical section of the same, similarly enlarged. Wenlock Limestone, Dormington.

As regards the "radial pillars," the following are the chief variations to be noted: —In the genus *Clathrodictyon*, Nich. and Mur., the radial pillars are incomplete, or even almost obsolete as distinct structures. In some forms of the group, such as *C. regulare*, Rosen, the radial pillars are confined to their respective interlaminar spaces, running from their lamina of origin to the lamina next above, but not being continued through more than one interlaminar space (Plate V, fig. 1). In *C. striatellum*, D'Orb., a nearly allied Silurian species, the pillars are not only confined to their respective interlaminar spaces, but many of them are imperfect, and fall short of the lamina next above that from which they arise (Plate V, fig. 3). In the more typical species of *Clathrodictyon*, such as *C. cellulosum*, Nich. and Murie, *C. vesiculosum*, Nich. and Mur., *C. variolare*, Rosen, and *C. fastigiatum*, n. sp., the concentric laminæ are crumpled into numerous minute undulations, which become continuous with the radial pillars. In these cases, therefore, the radial pillars become largely confounded with the concentric laminæ, the appearance exhibited by vertical sections (Fig. 2, A, and Fig. 3, B, and Plate V, figs. 5 and 6) being that of vesicular tissue composed of larger or smaller cells arranged in rows. The radial pillars in these cases have, however, nevertheless, a real existence, as shown by the fact that their cut ends can generally be recognised clearly in tangential sections (Fig. 2, B, and Fig. 3, A).

In the genus *Labechia*, E. and H., the radial pillars reach their maximum of development, being exceedingly stout, pointed at their free ends, and, as a rule, continuous from the epitheca to the upper surface (Fig. 5). In this genus, also, as to a less extent in some species of *Clathrodictyon*, adjoining pillars may become closely united by their sides, thus giving rise to short flexuous rows, or sometimes (as in *L. alveolaris*, n. sp., from the Wenlock Limestone) to a reticulated tissue not very unlike that of such "Tabulate Corals" as *Alveolites.*

As regards the genus *Actinostroma* in particular, and, indeed, as regards the Stromatoporoids generally, much question has arisen among different observers as to whether the radial pillars are hollow or solid. The earlier observers generally believed them to be the former; later observers, working mostly with thin sections, have generally maintained the latter view. For my own part, I have previously regarded the radial pillars as being solid; but more extended observations have shown me that this is certainly not invariably the case. In some forms (*e. g.* in certain species of *Actinostroma* and *Clathrodictyon*) no traces of any central aperture can be detected in cross-sections of the radial pillars. In other cases there is clear evidence of the existence of an axial tube in the pillars. At the same time, there is no ground for supposing, as was thought by many of the earlier observers, that the radial pillars were inhabited by zoöids, or that they are in any way comparable with the zoöidal tubes of *Millepora*. On the contrary, it is still uncertain if they were ever really open at their free extremities, even where, as in *Labechia*,

E. and H., there is clear evidence that they were hollow internally. Even where the surface carries perforated tubercles (as in *Stromatoporella laminata*, Barg., Pl. X, fig. 4), it remains to be shown that these tubercles are the upper ends of the radial pillars.

In various types of *Actinostroma*, such as *A. clathratum* (Plate I, figs. 10 and 13), tangential sections show that the exterior of the pillars is of a denser structure than the interior. The cut ends of the radial pillars thus show a dark external ring and an internal lighter space, or, in some cases, a dark outer ring and a minute central clear spot surrounded by a dark ring. This appearance, which is very distinct in some specimens, though not recognisable in others, would seem to show clearly that the radial pillars were primitively furnished with a minute central canal, which probably became largely or entirely filled up in the process of growth. There is no reason to think, however, that this axial canal opened on the surface, as the pillars in *Actinostroma clathratum* and its allies appear to end superficially in blunt imperforate tubercles (Plate II, fig. 11).

In *Labechia*, E. and H., similar appearances have been long since recognised as existing in a still more marked form (Steinmann "Ueber fossile Hydrozoen," 'Palæontographica,' 1878, Plate XII, figs. 10 and 11; and Nicholson, "Pal. Tabulate Corals," Plate XIV, fig. 4). Thus in tangential sections of *Labechia conferta*, Lonsd. (Fig. 5) one can almost always detect in the cut ends of the radial pillars a minute central dark or light spot, surrounded by a well-marked concentrically-laminated ring; and there is no reason to doubt that this central spot marks the position of a small central canal. That the same phenomenon is much less frequently recognisable in *vertical* sections, is easily explained by the fact that it is necessarily only an occasional thing for the section to cut a radial pillar precisely in the median plane. There is, however, evidence, as will be subsequently shown, that the radial pillars of *Labechia conferta* have really a cribriform structure. The central canals of the pillars are, in any case, of small size, and it is doubtful if they are continued to the summits of the pillars. The pillars, in fact, terminate superficially in blunt tubercles, which as a rule show no evident signs of a perforation at their summits (Plate III, fig. 12). In other specimens, however, there does appear to be an opening at the summits of some of the pillars (Plate III, fig. 14), though whether this appearance may not be the result of weathering is difficult to decide.

In a beautiful species of *Labechia* which I have found in the Devonian Limestones of South Devon, and which I shall name *L. serotina*, a much larger and more conspicuous axial canal is developed in the radial pillars (Fig. 4). Tangential sections of this species show that each of the radial pillars is traversed by a large central tube, which is seen in long sections to be crossed by numerous thick, curved, transverse partitions, to a large extent obliterating its cavity. I do not know the upper surface of this form, and cannot positively assert that the axial canals of the pillars may not sometimes be open above; but in those pillars which terminate

in the sections examined, the free end of the pillar is pointed, and the canal apparently ceases before the extremity is reached.

Still more remarkable phenomena are presented by a singular Stromatoporoid, of which I collected examples from the Devonian Limestones of Herborn, near Paffrath, and which I shall term provisionally *Hermatostroma Schlüteri*, as I am unable to refer it to any recorded genus or species. In this aberrant type (Fig. 1, p. 42, and Plate III, figs. 1 and 2) the general structure of the skeleton is like that of the normal Stromatoporoids, consisting of radial pillars and concentric laminæ; but the pillars are of unusual size, and are furnished with large axial canals. These canals are rendered exceedingly conspicuous by being filled with dark-coloured oxide of iron, and they are seen not only to occupy the axes of the pillars, but to send off branches which run along the radiating processes or arms

FIG. 4.

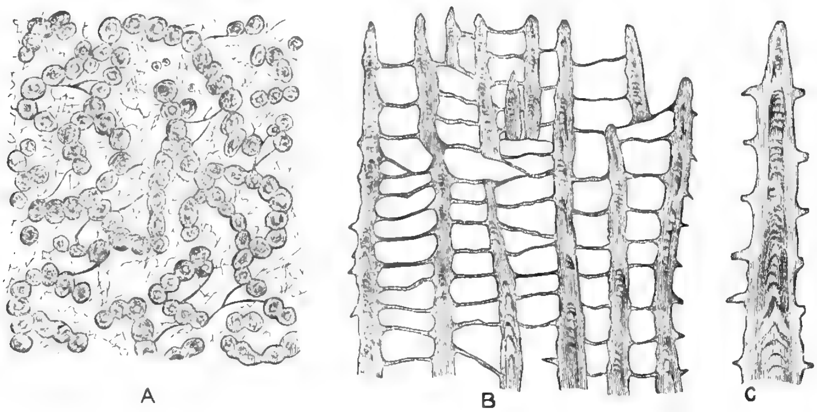


FIG. 4.—*Labechia serotina*, n. sp. Devonian, Teignmouth. A. Tangential section, enlarged twelve times, showing the arrangement of the pillars in short interlacing rows, and their large axial canals. B. Vertical section, similarly enlarged, showing the partitioning of the axial canals of the pillars by transverse plates, and the connection of the pillars by numerous horizontal "arms." C. A single radial pillar further enlarged, showing its pointed extremity.

which make up the concentric laminæ. In this case, therefore, not only are the radial pillars furnished with wide axial canals, but these canals are placed in direct communication with one another through the medium of the horizontal processes of the laminæ. None of my specimens show the upper surface, so that it is not possible to decide positively whether or not the axial canals opened on the surface. It would seem, however, probable that they did so, as they terminate in open orifices on the upper surfaces of the laminæ as exposed by concentric fractures.

The only point about the concentric laminæ which demands a moment's notice here is the question as to whether they are double or single in their constitution. Many observers have held that the concentric laminæ are composed each of two lamellæ, firmly united with one another in the mesial plane. The general fact that the result of rough fracture of specimens of the Stromatoporoids is invariably that

of laying bare the *surface* of the concentric laminæ, and never that of splitting them into two halves, would go to prove that the laminæ are not composed of two definite strata. The way in which they are developed, by the fusion of the horizontal connecting-processes or "arms" given out by the pillars, would still further confirm this view. At the same time, the concentric laminæ, when examined in thin vertical sections, often show phenomena which it is not easy to fully explain. In various types, the concentric laminæ exhibit a central darker band, with comparatively lighter-coloured calcareous tissue above and below (Plate I, fig. 1). In other cases, there seems to be a definite thin line dividing the lamina into an upper and lower half (Plate II, fig. 8). In various other types, such as *Stromatoporella granulata*, Nich. (Plate I, fig. 5), or *Stromatoporella eifeliensis*, n. sp. (Plate XI, fig. 1), the central plane of the lamina is marked by a distinct, clear, broad line with darker tissue on both sides, in which minute tubuli are seen. The case of those forms in which there is only a thin dark line in the centre of the lamina might perhaps be explained by supposing that the laminæ are at first very thin, and that they gradually become thickened by the deposition of fresh calcareous tissue both on their under and upper sides. In this case the dark central line would represent the original lamina. It seems to me, however, to be more probable that the inosculating fibres, out of which the laminæ are composed, are really hollow, each having an axial canal. This supposition is rendered exceedingly probable by the existence of forms, such as *Hermatostroma Schlüteri*, in which the axial canals in the radial pillars certainly send prolongations into the horizontal fibres out of which the concentric laminæ are made. On this view, the dark or light colour of the mesial line observable in the concentric laminæ of many Stromatoporoids would depend on whether these supposed canals were filled with calcite or with some opaque material.

(*d*) *The Interlaminar Spaces.*—The spaces between each successive pair of laminæ may be spoken of by the general name of the "interlaminar spaces." In theory, these spaces are continuous, but in reality they are minutely subdivided, and the subdivisions are to a varying extent in free communication with one another; while in certain forms they cease to have any existence as separate structures.

In such forms as *Actinostroma clathratum*, the interlaminar spaces are practically continuous, as they are simply broken up by the passage through them of the innumerable radial pillars which connect together successive laminæ, as also by such imperfect pillars as merely project into the interlaminar spaces from below. In such cases, also, the interlaminar spaces are all placed in direct communication with one another by means of the innumerable pores with which the concentric laminæ are perforated. In such forms, therefore, we may suppose that the whole system of the interlaminar spaces was filled with the cœnosarc and that the zoöids were given off at the surface of the last formed lamina.

On the other hand, in the genus *Stromatopora*, Goldf., where the cœnosteum is generally developed in "latilaminæ," and where the radial pillars are so conjoined with their horizontal arms as to give rise to a continuously reticulated skeleton, the interlaminar spaces, as such, can hardly be said to exist. They are, in fact, represented only by the irregular branches of communication between adjoining zoöidal tubes (Plate V figs. 11, 15 and 17). Hence, in these forms the vitality of the colony must at any given moment have been confined to the last formed latilamina.

In the *Labechiidæ*, again, it is difficult to arrive at any certain conclusions as to the true condition of the interlaminar spaces. If we regard the horizontal processes or "arms" given out by the radial pillars of *Labechia conferta*, Lonsd., as being actual *plates*, then there are no true interlaminar spaces. In place of interlaminar spaces, we should have a series of oblong or lenticular cells, occupying all the intervals between the pillars, and resembling the intertubular tissue of *Plasmopora* or the vesicular tissue of *Cystiphyllum*. If, on the other hand, we consider the horizontal connecting-processes of the radial pillars of *Labechia* (Fig. 5, c c) to be mere calcareous filaments, such as we see in *Actinostroma clathratum*, Nich., then the interlaminar spaces of *L. conferta*, Lonsd., are represented by a loose network of irregular, intercommunicating cellular cavities. Thin sections, unfortunately, are not conclusive on this point. The balance of evidence at present, derived both from thin sections and also from observations of the true surface or of fractured surfaces of *Labechia*, would seem to me to be in favour of the view that the connecting-processes in this genus are really in the form of tabular plates. If this view be correct, then there are no interlaminar spaces, strictly so-called, in *Labechia*, the condition of parts being very much what we find to exist in various "tabulate" Corals, such as *Fistulipora* or *Plasmopora*, except that the large tubes of the latter types are represented in *Labechia* by the "radial pillars." If this view be correct, it would follow further that only the very last formed layer of the

Fig. 5.

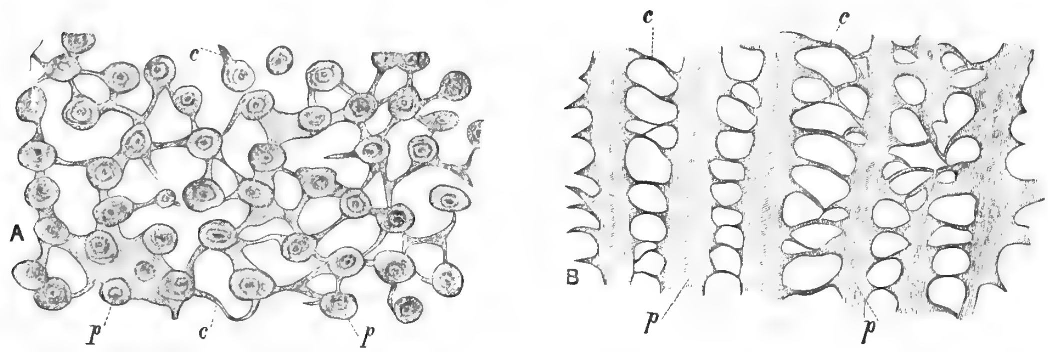


Fig. 5.—Sections of *Labechia conferta*, Lonsd., enlarged twelve times. Wenlock Limestone, Benthall. A. Tangential section. B. Vertical section. *p p.* Radial pillars. *c c.* Connecting-processes.

skeleton in *Labechia* could be truly alive, the cœnosarcal sheet and its zoöids being superior to the last-formed series of "tabulæ." Observations made upon such species of *Labechia* as *L. alveolaris*, n. sp., of the Wenlock Limestone, and *L. serotina*, n. sp., of the Devonian (Fig. 4), would strongly confirm the view here taken as to the tabular nature of the connecting-processes in the genus *Labechia*. It is quite certain, at any rate, that no differences whatever can be detected in thin sections between the connecting-processes in the species of *Labechia* just mentioned, and the "tabulæ" of such Corals as *Favosites* and *Alveolites*.

(*e*) *Zoöidal Tubes.*—The great difficulty which many observers have felt in the way of accepting the reference of the Stromatoporoids to the *Cœlenterata* is that no clear demonstration had been made of the existence in the skeleton of any tubes which might have lodged the zoöids of a Hydrozoan or Actinozoan colony. It was this difficulty which induced me previously to adhere to the reference of the group to the *Rhizopoda*. The first steps in the removal of this difficulty were taken by Carter in his researches on *Hydractinia*; but, after all, the thin crust of *Hydractinia* is in many respects very different to the huge masses of the larger Stromatoporoids, and it seemed only reasonable to expect that the latter, if Cœlenterate, ought to show in their skeleton traces of tubes, such as might have been inhabited by separate zoöids. Many observers have regarded the radial pillars as hollow, and as being such zoöidal tubes; but it is, I think, quite certain that this view is untenable. Even when hollow, the radial pillars seem to be mostly closed superficially; and where it may be surmised that they did open on the surface (as, perhaps, in *Hermatostroma Schlüteri*, Nich.), it still seems certain that they did not lodge zoöids, the cavities for which can, indeed, be shown to exist elsewhere. Such cases can, in fact, be parallelled by what we see in *Hydractinia circumvestiens*, Wood (Plate VI, figs. 8 and 9), in which definite zoöidal tubes coexist with large perforated pillars.

The most complete demonstration of the existence of definite zoöidal tubes is obtained from the examination of the skeleton of the genus *Stromatopora*,[1] Goldf., and of those allied types which make up the "Milleporoid" section of the Stromatoporoids. In these forms the skeleton is essentially composed of vermiculate and reticulated calcareous fibres, forming a more or less continuous framework, which is only roughly and imperfectly divisible into radial and concentric elements. The skeleton has in fact a close general resemblance to that of the recent *Millepora*, except that the tubes which traverse it are, as a rule at any rate, not divisible into two distinct series, differing from one another in point of size. The skeleton in these forms is, however, penetrated by numerous minute, flexuous, but essentially parallel, vertical tubes (Plate V, figs. 10, 13 and 15), which are not bounded by definite walls but are

[1] It must not be forgotten that the forms understood here under the name of *Stromatopora* are those of the type of the true *Stromatopora concentrica*, Goldf., and are therefore wholly distinct from those which have usually been grouped under *Stromatopora*.

simply enclosed by the vermiculate fibres of the cœnosteum, precisely as are the zoöidal tubes in *Millepora*. There is, it need hardly be pointed out, no relationship between the tubes here in question and the occasionally present axial tubes of the radial pillars; nor have these tubes anything in common with the comparatively large *walled* tubes of the so-called "*Caunoporæ*," whatever view we may take as to the nature of these latter structures. There can not, in fact, be the smallest question but that the minute vertical tubes of *Stromatopora* belong to the cœnosteum proper; nor does there appear to be any reasonable ground for doubting that they served for the lodgment of the zoöids of the colony. This conclusion is, in my opinion, rendered absolutely certain by the fact that in all the typical species

FIG. 6.

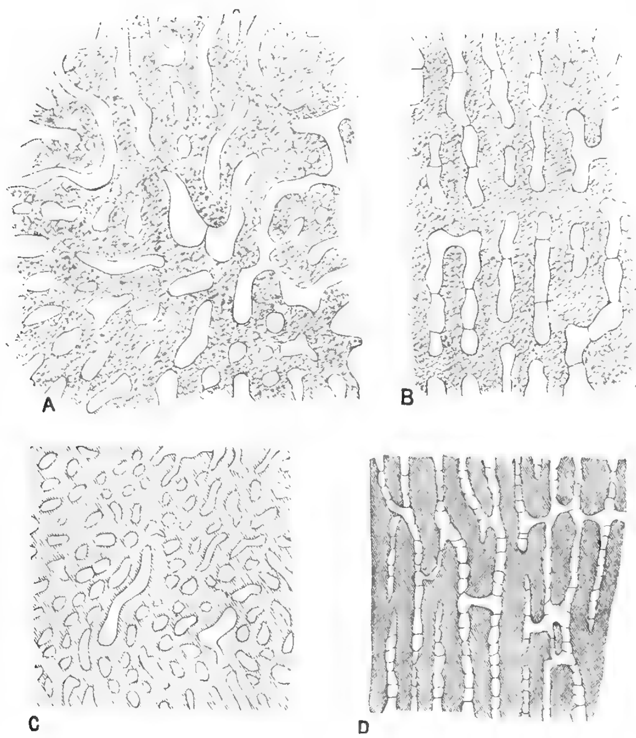


FIG. 6.—A. Tangential section of *Stromatopora Hüpschii*, Barg., sp., enlarged twelve times, showing the reticulate skeleton and the porous structure of the skeleton-fibre. B. Vertical section of the same, similarly enlarged, showing the tabulate zoöidal tubes. C. Tangential section of *Stromatopora bücheliensis*, Barg., sp., enlarged twelve times. D. Vertical section of the same, similarly enlarged. From the Devonian Limestone of Büchel (Paffrath district). Both these forms commonly occur in the "*Caunopora*" state, and were referred by Bargatzky to *Caunopora*, Phill.

of the genus *Stromatopora* (such as *S. concentrica*, Goldf., *S. Hüpschii*, Barg., *S. bücheliensis*, Barg., *S. antiqua*, Nich. and Mur., *S. discoidea*, Lonsd., *S. typica*, Rosen, *S. Beuthii*, Barg., *S. Carteri*, Nich., &c.), these vertical tubes are crossed by more or less numerous, complete, transverse, calcareous plates, which in all respects agree precisely with the "tabulæ" of the Hydrocoralline genus *Millepora* and of the so-called "tabulate" Corals. I give here sketches of two characteristic species of

Stromatopora (viz. *S. Hüpschii*, Barg., and *S. bücheliensis*, Barg.), which occur in the Devonian formation of both Britain and Germany, and in which these partitions in the zoöidal tubes are very well shown (Fig. 6). Nor do I see, for my own part, any reason for doubting that these transverse partitions in the zoöidal tubes agreed in function, as they undoubtedly do in structure and position, with the "tabulæ" in the tubes of *Millepora*. If this be admitted, we have in the genus *Stromatopora*, Goldf.—and I am not aware that this fact has been previously clearly demonstrated —a group of Stromatoporoids in which *the skeleton was provided with distinct tabulate tubes in which the individual zoöids were contained.*

Moreover, with the recognition of this fact it becomes comparatively easy to demonstrate the existence of similar zoöidal tubes in other Stromatoporoids, in which they occur in a more imperfect and less completely developed form. Thus, in *Stromatoporella granulata*, Nich., as in the closely allied *Stromatoporella eifeliensis*, n. sp., thin sections show the existence of short, irregularly distributed, vertical tubes, which rarely extend through more than two or three interlaminar spaces, and which are here and there crossed by irregular tabulæ. The existence of these tubes can be recognised in both tangential and vertical sections (Plate I, fig. 15, and Plate II, figs. 9 and 10); and they appear to open on the surface by elevated tubercles perforated by round apertures (Plate I, fig. 14, and Plate IV, fig. 6.) It can hardly be doubted that we have here an imperfect form of the tabulate zoöidal tubes of the typical *Stromatoporæ*.

Well-developed tabulate zoöidal tubes, in all respects essentially similar to those of *Stromatopora*, Goldf., may also be recognised, in a more or less complete form, in such genera as *Idiostroma*, Winch., and *Stachyodes*, Barg.

The forms in which definite zoöidal tubes are least developed and least easily recognised as existing at all are those which have usually been regarded as the typical *Stromatoporæ*, namely, those which I shall place under the genus *Actinostroma*, together with such types as *Clathrodictyon*, Nich. and Mur. If, for example, we take such a type as *Actinostroma clathratum* (the *Stromatopora concentrica* of most authors) and compare the skeleton with that of *Hydractinia echinata*, Flem., we have little difficulty in recognising the cavities in which the zoöids were contained, though definite zoöidal tubes such as those of *Stromatopora* proper are not developed. We recognise, in fact, that anything of the nature of actual *tubes* is not required by the necessities of the case. In the early condition of the cœnosteum in *Hydractinia echinata*, the outer surface of the horny crust is covered by the cœnosarc, as a thin layer from which the zoöids are given off. Similarly, in the earliest condition of the skeleton in the genus *Labechia*, E. and H., there do not seem to have been any superficial apertures; but the zoöids must have been given off from the layer of cœnosarc covering the first-formed layer of the skeleton. This is well shown in the example figured in Plate III, figs. 9 and 10, which may be

either a very young specimen of *L. conferta*, Lonsd., or perhaps a new species. In this specimen the cœnosteum is a thin discoid expansion, covered below by a delicate striated epitheca, which bears superiorly a single layer of blunt imperforate tubercles; there being no traces of superficial apertures, nor any room for the existence of vertical tubes. In the adult *Labechia conferta*, Lonsd., it seems probable that the zoöids were likewise given off from the surface-layer of the cœnosarc; the principal change effected in the course of growth being, that as the radial pillars grew upwards the spaces between them became divided into cellular compartments by the development of curved calcareous plates. In the adult *Hydractinia echinata*, on the other hand, the successively formed layers of the cœnosteum are not absolutely imperforate but are traversed by numerous minute pores, by which the entire cœnosarc is kept in organic connection, and from the last series of which the zoöids are emitted.

In *Actinostroma clathratum*, Nich., and its immediate allies, the concentric laminæ are, as has been already pointed out, minutely porous (Plate I, figs. 8 and 11). They are composed of calcareous filaments so interlaced as to leave between them innumerable minute apertures, which pass through the laminæ and place successive interlaminar spaces in direct communication. The existence of such pores can generally be made out by a simple examination of the surface with a hand lens, and always by means of properly prepared thin sections taken parallel to the laminæ. In *Actinostroma clathratum* itself these pores are simply the wide angular meshes formed by the inosculation of the horizontal arms which are thrown out from the pillars; and it seems certain that their function must have been that of transmitting stolons by which the cœnosarc in successive interlaminar spaces was bound together. We may also reasonably suppose that in the last formed and most superficial concentric lamina the pores would correspond with the points at which the separate zoöids were budded off, and that these openings therefore represent zoöidal tubes.

As to whether or not *dimorphism* of the colony occurs in any of the Stromatoporoids, it is not easy to speak with certainty. Mr. Champernowne has been good enough to furnish me with examples of a species of *Stromatopora*—apparently an undescribed form—in which scattered among the ordinary tubes are tolerably regularly placed tubes of larger size, both sets of tubes being tabulate. This can hardly be interpreted as other than a case of dimorphism; but it appears to be an exceptional case, and I have not been able in the other species of *Stromatopora* to recognise any marked or constant differences between different zoöidal tubes. When we consider, however, how slight, comparatively speaking, are the differences between the gastropores and the dactylopores of the cœnosteum of *Millepora*, it may be conjectured that dimorphism may well have existed generally in the genus *Stromatopora*, without our being able to demonstrate this from the hard parts alone.

It is also almost certain that the large tabulate axial tubes of such genera as *Idiostroma*, Winch., *Stachyodes*, Barg., and *Amphipora*, Schulz, with their lateral branches, served for the lodgment of a special series of zoöids; but we have at present no absolutely final evidence on this point. If, moreover, it were possible to show that the large, thick-walled, tabulate tubes which characterise the so-called genera *Caunopora*, Phill., and *Diapora*, Barg., really formed a constituent portion of the Stromatoporoids in which they are found, we should have had in these an admirable example of dimorphism. Indeed, the comparisons which have been made by earlier observers between the Stromatoporoids and the recent *Millepora* have usually been based upon specimens of "*Caunopora*." The real nature of the tubes in question in *Caunopora* and *Diapora* is, however, a subject involved in such difficulty, that I shall consider it in a separate section.

(*f*) *The Astrorhizæ.*—One of the most prominent features in many Stromatoporoids is the presence on the surface, and also at all deeper levels in the skeleton, of numerous shallow grooves arranged in definite stellate systems upon the surfaces of the concentric laminæ (Plate IV, figs. 2 and 6). For these stellate canal-systems Mr. Carter's apt name of "astrorhizæ" may be employed with advantage. There is, also, no reason to doubt that Mr. Carter has decided correctly in his determination of these structures as the homologues of the branching cœnosarcal grooves on the surface of the skeleton of many *Hydractiniæ* (Plate VI, figs 3 and 9). They may also be compared with the branching and inosculating cœnosarcal canals of the cœnosteum of *Millepora* (Plate IV, fig. 5). The correctness of this view seems to be sufficiently proved by a consideration of various other facts which are now known as to the structure of the skeleton in various Stromatoporoids, and especially by the fact that many of them can be proved to have possessed tabulate zoöidal tubes. At the same time, it should be remembered that, in the absence of this confirmatory evidence, earlier observers were not without justification in comparing the astrorhizæ of the Stromatoporoids, as many have done, with the dermal canals of certain of the Sponges.

The size of the astrorhizæ is very variable in different types of Stromatoporoids, but, when present at all, they are always visible to the eye, and they are often extremely conspicuous objects (Plate IV, fig. 2). Whatever their size may be, their general form is tolerably constant, each astrorhiza consisting of a stellate group of comparatively large-sized shallow gutters, which spring from a central point and branch as they radiate outwards, diminishing at the same time in diameter, and giving off more or less numerous lateral branches. These branchlets communicate freely, and they finally inosculate with the terminal twigs of adjoining astrorhizæ (Plate III, fig. 3). The entire series of astrorhizæ thus forms a system of shallow, open, anastomosing grooves on the surface of the cœnosteum, and doubtless served for the lodgment of corresponding cœnosarcal stolons.

As the astrorhizæ are mere grooves on the surface of the last-formed layer of the skeleton, in their typical condition at any rate, it follows that they are not only present on the free surface of the colony, but also on the surface of successive concentric laminæ; since each lamina in turn constituted for a time the actual surface. As, however, each successive lamina is produced, the astrorhizal grooves on the surface of the lamina below necessarily become roofed over by the new layer, and are thus converted, in all the parts of the skeleton below the surface-lamina, from open *grooves* into *canals.* Hence, in vertical sections of such Stromatoporoids as possess astrorhizæ, the cut ends of the astrorhizal canals appear in the section at various points as larger or smaller round apertures (Plate V, fig. 6, and Plate XI, figs. 12 and 14). They are, however, necessarily *without any proper walls*, their lower margin being formed by the lamina to which they belong, their upper margin by the lamina next above, and their sides by the irregular radial pillars which connect these two laminæ.

There is one Stromatoporoid, viz. *Stromatopora discoidea*, Lonsd. (= *S. elegans*, Rosen), from the Wenlock Limestone of Sweden, Esthonia, and Britain, in which the astrorhizal canals seem to depart in important respects from their ordinary form. The elucidation of the true structure of this singular type is attended with unusual difficulties, as, for some reason difficult to explain, most specimens have undergone a more or less complete secondary crystallisation of their skeleton, even when the surface-characters are retained in admirable preservation. Superficially regarded, *S. discoidea*, Lonsd., is remarkable for the generally large size of the astrorhizæ, for the minute subdivision of the main channels, and for the extremely perfect inosculation established between the entire system of astrorhizæ (Plate III, fig. 3). Thin sections show, however, that the astrorhizal canals are not, as usual, mere shallow grooves on the surfaces of the successive laminæ, but that the laminæ are obsolete, and the astrorhizal canals are converted into comparatively deep channels, with perpendicular sides which extend downwards through the thickness of each successive "latilamina." In other words, beginning as open grooves on the surface of the primitive crust, the sides of the astrorhizal canals grew upwards to form so many deep narrow channels with vertical walls, these channels extending through the whole of the first "latilamina." When the second "latilamina" is formed, new astrorhizal grooves are produced, which pass through the same process of development; and so on through the entire system of "latilaminæ" of which the skeleton is made up. Moreover, the tabulate zoöidal tubes open into the sides of these deep channels, and are, in fact, confluent with them. Perhaps, therefore, the most correct way of regarding the astrorhizal grooves of *S. discoidea*, Lonsd., would be to consider them as really formed by the serial junction of the zoöidal tubes in sinuous lines, much as we see in the serially-united polypes of *Diploria* and other types of Corals. Be this as it may, the result of the peculiar constitution of the astrorhizal system

in *Stromatopora discoidea*, Lonsd., is that we get very different appearances in thin sections to those presented by the normal *Stromatoporæ*. Thus, in tangential sections (Plate VII, fig. 1) the grooves representing the astrorhizal canals are seen to be constant in form and position at whatever level in the "latilamina" the section may have been taken. In vertical sections, further, we do not see the round apertures representing the cut ends of the radiating astrorhizal canals, but in place of these we observe (Plate VII, fig. 2) deep vertical fissures, which are in many places crossed by transverse "tabulæ," and which clearly represent, in large part at any rate, the zoöidal tubes.

In those Stromatoporoids which possess astrorhizæ, there arises an important distinction according as the astrorhizæ of successive laminæ are produced irregularly, or are developed one above the other in a system of vertically superposed groups. In the latter case, the astrorhizæ of each vertical series are connected together by an approximately vertical central tube, which opens on the surface of the cœnosteum by a distinct aperture, from which the grooves of the last-formed astrorhiza radiate (Plate III, figs. 4 and 6, and Plate IV, fig. 6). The opening of this central canal is often placed on a more or less conspicuous "monticule," and Bargatzky conjectures that the existence of such monticules or "warts" may be taken as a general indication of the presence of vertically superimposed astrorhizæ. Prof. Ferd. Roemer has doubted the existence of such vertical central canals to the astrorhizal groups, and has explained the phenomena presented by these as being really produced, in a manner formerly alluded to, by the inclusion of the tubes of *Spirorbis* in the tissues of the growing Stromatoporoid. An examination of thin sections, however, shows this supposition to be baseless, though such imbedded *Spirorbes* do occur not infrequently. Thin sections, in fact, entirely confirm the conclusion which one would naturally draw from the regular distribution of these prominent apertures on the surface of many Stromatoporoids (see Plate III, figs. 4 and 6)—the conclusion, namely, that they are the apertures of canals belonging to the cœnosteum itself. These axial canals of the astrorhizæ are wholly devoid of proper *walls*, as is also the case with the radiating canals of the astrorhizæ, and they cannot, therefore, be confounded with the wholly different *walled* tubes of the so-called *Caunoporæ*. As regards their function, we may suppose that these axial astrorhizal canals lodged primary stolons of the cœnosarc, from which were given off the radiating and inosculating stolons occupying the grooves of the astrorhizæ. There does not seem, certainly, to be any ground for regarding these canals as having served for the lodgment of zoöids.

Certain types of Stromatoporoids are apparently wholly destitute of astrorhizæ. I have, for example, failed to detect any definite representatives of these structures in any species of *Labechia*. Other types, again, appear to constantly possess these structures. They are, in fact, present in so many Stromatoporoids, of the most

diverse affinities, that they cannot, in my opinion, be employed with any advantage as constituting by their presence a *generic* character. Hence I have not thought it expedient to retain Winchell's genus *Cœnostroma*, in the definition of which the presence of astrorhizæ is taken as the essential character. On the other hand, I cannot agree with Prof. Ferd. Roemer ('Leth. Pal.,' p. 532) in thinking that they are of quite variable occurrence, and that they have not even a *specific* value. My experience is that the astrorhizæ are, in general, quite constant in their absence or presence, and also in their characters when present, in types which can be otherwise shown to belong to the same species; and that they can, therefore, be used as marks of specific distinction. It must be admitted, however, that there are Stromatoporoids which are otherwise very similar to one another in general structure, but which in some cases possess astrorhizæ, whereas at other times they appear to be without these structures. In such cases, all that can at present be said, is that a careful and extended series of microscopic observations will be needed, before we can assert positively that such types are not distinguishable by any other characters than the presence or absence of astrorhizal canals.

(*g*) *Astrorhizal Tabulæ.*—In *Stromatopora? dartingtonensis*, Cart., Mr. Carter has described transverse calcareous partitions as developed in the astrorhizal canals, which in this particular type are usually of large size ('Annals and Mag. Nat.

FIG. 7.

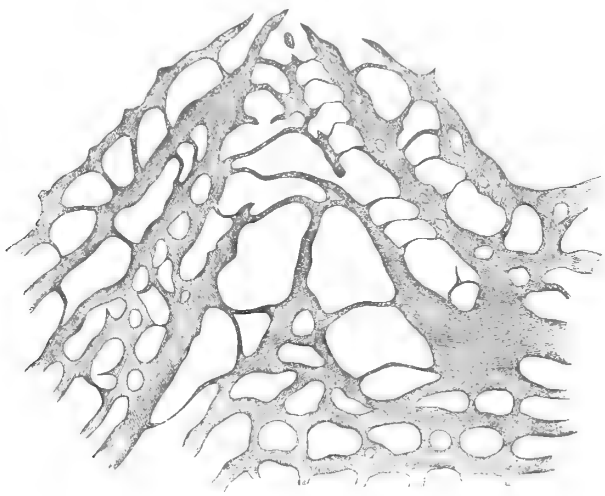


FIG. 7.—Vertical section through the centre of one of the astrorhizæ of *Stromatoporella eifeliensis*, Nich., enlarged twelve times, showing the central canal of the astrorhiza and the numerous "astrorhizal tabulæ" in the larger radiating canals. Middle Devonian; Gerolstein, Eifel.

Hist.,' ser. 5, vol. vi, p. 339). The same observer has also compared these transverse partitions with the "tabulæ" in the zoöidal tubes of *Millepora*. As the astrorhizal canals appear to me to be in no way homologous with the zoöidal tubes of *Millepora*, and as many Stromatoporoids have truly tabulate zoöidal tubes, I

shall speak of the structures now in question as "astrorhizal tabulæ." So far as I have seen, these structures can almost always be recognised in thin sections of *Stromatopora? dartingtonensis*, Cart.; but they are by no means peculiar to this species. Similar structures in an equally well-developed form, occur in *Stromatoporella eifeliensis*, n. sp., and they are present more or less commonly in various other types. Even in those forms in which they may be said to be of constant occurrence, they have, however, a very variable development, and they likewise vary much in form. In most cases they have the form of complete calcareous plates, which are placed at irregular intervals across both the larger and smaller astrorhizal canals, but principally in the former (Fig. 7). They may be straight or curved, or even funnel-shaped or vesicular, as, for example, they sometimes are in *Stromatoporella laminata*, Barg. They doubtless indicate the periodically produced lines of demarcation between the superficial and still active portions of the colony and the deeper dead portions of the mass; but it is difficult to assign to them, with our present knowledge, any further function.

(*h*) *Axial Tubes.*—In certain anomalous types of Stromatoporoids there occur tubes which may be distinguished by their position and other characters from the astrorhizal canals or the ordinary zoöidal tubes. The tubes in question are of large size; they have a definite relation to the entire organism; they are definitely circumscribed by the general tissue of the cœnosteum; and they are usually, if not always, intersected by distinct calcareous plates or "tabulæ." Except in the presence of a thickened *proper wall*, the well-known tubes of the so-called "*Caunoporæ*" have very similar characters, and it might therefore have been natural to consider the distinctive tubes of the forms included under the head of *Caunopora*, Phill., and *Diapora*, Barg., in this place also. Many reasons have, however, induced me to devote a special section to the consideration of these latter fossils. The tubes to which I now specially refer, and which I shall distinguish by the name of "axial tubes," are found, in their most marked form at any rate, only in certain aberrant genera of Stromatoporoids, namely *Idiostroma*, Winch., *Amphipora*, Schulz, *Stachyodes*, Barg., and *Beatricea*, Bill. The axial tube of the last of these is, however, in many respects peculiar, and I need here only speak of the three first-named genera. All these form, typically, cylindrical colonies, sometimes branched or multiple, sometimes simple, rooted basally, and having a general resemblance to the dendroid species of *Favosites* or *Pachypora*. In the above three genera, the cylindrical cœnosteum is traversed by a large axial canal, which may be single, or which may be accompanied by a small but variable number of lesser but otherwise similar canals, running parallel with the main tube and at a little distance around it. Both the axial tube and the smaller tubes (when the latter are present) are definitely circumscribed, and have their internal cavities intersected by transverse calcareous plates or "tabulæ." These tabulæ may run directly across

the axial tube, as generally in *Stachyodes* (Plate VIII, fig. 10), or they may be curved, or even regularly funnel-shaped. They often have the form last mentioned in the genus *Idiostroma,* Winch., and they then show a curious resemblance to the tabulæ in the genus *Syringopora.* As a rule, the axial tube gives off smaller lateral branches, which ascend in the substance of the cœnosteum, dividing as they proceed. These are also furnished with tabulæ, and appear to be directly connected with the general interspaces of the skeleton. Whether the axial tube and its ascending lateral branches open finally upon the surface is a point on which it is difficult to obtain conclusive evidence; but there are strong reasons for thinking that they certainly do so.

Now, it is certain that these tubes, whatever may be their function and nature, are veritable constituents of the organisms in which they are found. Whatever may be the nature of the "tubes" in "*Caunopora,*" it is not admissible to regard the tubes above alluded to as being parasitic structures, or as otherwise foreign to the Stromatoporoid in which they occur. They hold a definite position in relation to the rest of the organism, they communicate with the cavities of the general skeleton by apertures in their walls, they often give off branching lateral canals, and they are invariably present in the genera which they characterise. These considerations render it certain that these tubes are truly portions of the organisms in which they occur.

With regard, however, to the *function* of these axial tabulate tubes in *Idiostroma, Amphipora,* and *Stachyodes,* there is not at present sufficient evidence to warrant any very definite hypothesis. Perhaps the most probable theory that we can in the meanwhile form as to their nature is that the main axial tube lodged a stolon or axis of the cœnosarc, and that the lateral branched tubes in connection with this were occupied by a special series of zoöids. There are, also, some considerations which would render it not wholly unlikely that these tubes were connected with the process of reproduction, and lodged the generative zoöids. Apart, however, from all theories as to their nature, it may be pointed out that the existence of such tubes as a constituent portion of the cœnosteum of certain Stromatoporoids, deprives the hypothesis that the walled tubes of "*Caunopora*" also belong to the organism, of part of the inherent improbability that would otherwise attach to it.

(*i*) *The Epitheca.*—In a very large number of Stromatoporoids the under surface of the cœnosteum is covered by a thin, imperforate, concentrically striated, calcareous membrane (Plate III, figs. 7, 8, and 9), which has all the characters of the "epitheca" of many composite Corals, and to which the same name may be applied. In microscopic structure it appears to be merely composed of granular calcareous matter. Very many of the Stromatoporoids appear to constantly possess an epitheca, which in general arrangement and appearance is precisely similar to the

epithecal membrane in the massive species of *Favosites*, *Alveolites*, *Heliolites*, *&c.* When such forms are attached to foreign objects, the attachment usually takes place by means of a narrow peduncle; and if we sometimes find such types to be attached by a wide base, this is only what we also see occasionally in such corals as *Favosites gotlandica*, Lam., *Heliolites interstincta*, Wahl., and other similar types. Still, such forms are in no way "encrusting" types; and we sometimes meet with even large specimens in which the entire under surface is covered by the epitheca, and is at the same time deeply concave; so that the primitive condition of attachment to some foreign body appears to have been merely temporary.

In other forms, such as *Actinostroma clathratum*, Nich., an epitheca may be developed; but more commonly this structure is wanting, and the organism has simply grown in a succession of superimposed strata, applied first to some foreign body and then to one another. In a third group of forms, the organism seems to have been mainly or exclusively "encrusting" in its habit, the entire lower surface being applied to some foreign body, and no epitheca being developed. This is the case, for example, with certain of the so-called *Stromatopora polymorpha* group of forms (*e.g.* *S. curiosa*, Barg.), and is also common, though not universal, in *Stromatoporella eifeliensis*, Nich. Lastly, in the dendroid types, such as *Amphipora ramosa*, Phill. sp., and *Stachyodes verticillata*, M'Coy, sp., the colony resembled that of the ordinary dendroid Corals in being fixed at its base and in having no epitheca.

(*j*) *The Surface.*—The condition of the external surface in the Stromatoporoids can be studied only in specimens in a condition of very good preservation. In some essential respects the surface of any concentric lamina, at *any* depth, doubtless represents the condition of the exterior; since each lamina in turn formed for a time the free surface. We are, however, hardly justified in assuming that this is entirely or invariably the case. The most remarkable phenomenon in this connection is the occasional development, in certain specimens, over a part or the whole of the surface, of a thin, apparently structureless, calcareous membrane, largely or wholly imperforate. A somewhat similar phenomenon, though probably one of a totally different significance, is occasionally observed in certain of the *Favositidæ* (*e.g.* *F. tuberosa*, Rom.). Various Stromatoporoids show this curious phenomenon. Thus it occurs commonly in various encrusting types from the Devonian Rocks (Plate II, fig. 14), such as some of those which Goldfuss included under the name of *Stromatopora polymorpha* ('Petref. Germ.,' Pl. LXIV, fig. 8, *d*). It is seen in the *Stromatoporella* (?) *nulliporoides*, Nich., of the Devonian of North America, and apparently also in the similar or identical "*Cœnostroma*" *incrustans*, Hall and Whitfield (Plate III, fig. 6). The same thing is seen in *Stromatoporella granulata*, Nich., from the Devonian of Canada, well-preserved specimens of which often show over parts of the surface a thin calcareous membrane, pierced at intervals by minute elevated openings (Plate IV, fig. 6). Similar phenomena are observable, not uncommonly,

in specimens of *Idiostroma* and of *Stachyodes verticillata*, M'Coy (Plate VIII, fig. 12). The form, however, which displays this membrane most completely is the singular *Amphipora ramosa*, Phill. (Plate IX, fig. 1), in which many examples have the surface entirely covered with an apparently imperforate calcareous envelope. In this case, however, it can be shown, that underneath this membrane, between it and the true surface, are developed numerous comparatively large-sized lenticular vesicles. I am disposed to regard these marginal vesicles as corresponding to the "ampullæ" which have been shown by Professor Moseley to contain the gonophores in the recent Stylasterids. If this view be accepted, it seems probable that the development of the calcareous pellicle above alluded to, in all those Stromatoporoids in which it occurs, is connected with the formation of the reproductive zoöids. I shall, however, have occasion to refer to this point again.

In all the species of *Actinostroma*, such as *A. clathratum*, the surface (Plate II, fig. 11) is studded, in well-preserved examples, with numerous minute projecting tubercles, which are simply the upper ends of the radial pillars, and represent the small spines in *Hydractinia*. I have never succeeded in detecting any apertures in these tubercles, but it is possible that such exist.

In the nearly allied genus *Clathrodictyon*, Nich. and Mur., either the surface is covered with tubercles similar to those of *Actinostroma* (Plate II, fig. 12), or the tubercles have coalesced with one another to form vermiculate ridges (Plate II, fig. 13).

In the genus *Labechia*, E. and H., the upper ends of the radial pillars project above the surface as prominent tubercles (Plate III, fig. 12), much in the same way as in *Actinostroma*, except that, owing to the stoutness of the pillars, the tubercles are much more pronounced. The tubercles may be quite separate, or they may be partially confluent, so as to form sinuous rows (Plate III, fig. 13), these variations occurring in individuals of the same species (e. g. *L. conferta*, Lonsd.). In some species, however, as in *L. serotina*, n. sp. (Fig. 4), and *L. alveolaris*, n. sp., the tubercles coalesce so as to form a sort of labyrinthine pattern, after the fashion of the corallites in the genus *Halysites*. Whether the tubercles in *Labechia* are perforated or solid, is a point very difficult to determine positively. In some forms, such as *L. serotina*, they certainly would seem to be solid. In others, such as *L. conferta*, Lonsd., they sometimes have all the appearance of being solid, while at other times they show distinct round pits at their summits (Plate III, fig. 14); but it is quite possible that this latter phenomenon may be simply the result of weathering.

In a large number of Stromatoporoids the surface normally shows larger or smaller conical eminences, which may be distinguished from the granules and tubercles formed by the upper ends of the radial pillars under the name of "mamelons" or "monticules" (the "Warzen" and "Höcker" of German writers).

These are well seen in such types as *Stromatopora concentrica*, Gold., var. *colliculata*, Nich. (Plate III, fig. 5), and *Actinostroma verrucosum*, Goldf., sp.; but they occur in various types of diverse affinities. Sometimes these monticules are small and pointed, sometimes they are large and blunt, and sometimes they coalesce into ridges. In some cases they do not appear to be perforated at their summits, and they seem to have no special connection with the astrorhizæ. In many cases, however, each monticule corresponds with the centre of an astrorhizal system; and in such cases each is perforated at its summit by one or more comparatively large apertures (Plate III, figs. 4 and 6). These apertures at the summits of the monticules are what have been regarded as "oscula" by those who, like myself at one time, have upheld the reference of the Stromatoporoids to the Sponges. The possession of perforated monticules is a phenomenon which is specially characteristic of such Stromatoporoids as have astrorhizæ in regularly superposed groups; each vertical series having a central canal, from which the astrorhizæ of successive laminæ spring, and which ultimately opens on the surface (Fig. 7). Prof. Ferd. Roemer, as formerly pointed out, has endeavoured to explain away the existence of any such openings, as being merely formed by the inclusion in the growing Stromatoporoid of the tubes of *Spirorbis*; but I have often seen surface-openings produced in this way, and they are entirely different to those now in question. The latter can be shown conclusively, by means of thin sections, to belong to the Stromatoporoid in which they are found, and to be formed in the way I have above described; this conclusion being the one which we should have been otherwise led to draw from the great regularity with which these monticules and their openings are disposed in many types. There are, in fact, certain species in which the skeleton may be said to be built up of a series of cylinders, each terminating on the surface by a perforated prominence, and being traversed longitudinally by a median canal from which the astrorhizæ are given off. It is, however, to be noted that there are, on the other hand, certain types having well developed astrorhizæ arranged in more or less regular vertical rows, but not having the surface covered with monticules corresponding with the centres of the astrorhizæ. This condition of things occurs, for example, in *Stromatopora typica*, Rosen.

In a great many Stromatoporoids it is not possible to recognise with any distinctness any definite superficial apertures which might have served for the emission of zoöids. In a large number of cases this is probably only due to the fact that when these openings are filled with the matrix it becomes difficult or impossible, owing to their minute size, to detect their presence at all, except in specimens preserved in quite exceptional perfection. In other cases, as in young examples of *Labechia conferta*, Lonsd. (Plate III, fig. 10), the apparent absence of surface-perforations seems to be due to a real want of any apertures, the zoöids having been given off from the surface-investment of the cœnosarc. In weathered examples

of the genus *Actinostroma* (such as *A. clathratum*), it is often possible to recognise the angular meshes formed by the inosculating horizontal " arms " given out by the radial pillars, and we have seen that these meshes in all probability represent the zoöidal apertures.

On the other hand, in all the typical species of the genus *Stromatopora*, Goldf., well-preserved examples exhibit the rounded, oval, or vermiculate apertures of the zoöidal tubes. In many of such forms, therefore, the general aspect of the surface is exceedingly like that of an *Alveolites* or *Pachypora*, except that the zoöidal openings are mostly smaller than they are in the Corals just alluded to. Precisely similar apertures are seen on the surface of the species of *Idiostroma* (Pl. IX, fig. 9), *Stachyodes*, Barg. (Pl. VIII, fig. 12), and certain examples of *Amphipora ramosa*, Phill., sp. In the genus *Stromatoporella*, the surface in well-preserved examples exhibits rounded tubercles, which are perforated at their summits by round apertures which can hardly be anything else than the openings of the zoöidal tubes. These are well seen in specimens of *Stromatoporella granulata*, Nich. (Pl. I, fig. 14), and *S.* (*Diapora*) *laminata*, Barg. (Pl. X, fig. 4).

The conspicuous round apertures which are seen on the surface of specimens of *Caunopora*, Phill., cannot be considered apart from the question of the walled tubes to which they belong—a question which will be fully dealt with at a later period.

Lastly, the surface of many Stromatoporoids exhibits the astrorhizæ and their canals. These, when present, vary much in size, but it is unnecessary to say more about their characters here. As has been already seen, they are often apparently entirely absent in certain species, even when present in closely allied types. This, however, cannot be considered as surprising, when it is remembered that the corresponding cœnosarcal canals of *Hydractinia*, though so characteristic of many species, are said to be wanting in certain forms of the genus.

(*k*) *The Reproductive Organs.*—As regards most of the Stromatoporoids, the process of reproduction is wholly unknown. Accepting, however, the relationship of the Stromatoporoids to the *Hydrocorallinæ*, it would be naturally expected that the reproductive zoöids should have been lodged in special cavities within the skeleton, such as have been described by Professor Moseley in the case of the *Stylasteridæ*, under the name of "ampullæ." As a matter of fact, structures which do appear to be of the nature of "ampullæ," are to be recognised in certain of the Stromatoporoids. Thus, as has already been alluded to, many examples of *Amphipora ramosa*, Phill., possess a series of large-sized lenticular vesicles, which form a sort of marginal zone to the cylindrical cœnosteum, and which are covered over by a thin calcareous membrane (Pl. IX, figs. 2 and 3). Many examples of this species are, however, wholly destitute of these "marginal vesicles" and of the membrane which encloses these (Pl. IX, fig. 4). From their form and position, as

well as from their only occasional development, it seems a not unreasonable conjecture that these "marginal vesicles" gave lodgment to the reproductive zoöids, and that they are, therefore, of the nature of "ampullæ."

In the Devonian Rocks of Devonshire, and also, more abundantly, in the same deposits in the Paffrath district, I have found a Stromatoporoid, which I think to be probably identical with the *Stromatopora* (*Tragos*) *capitata* of Goldfuss. As the cœnosteum of this form is traversed by irregular tabulate tubes of a much larger size than the ordinary zoöidal tubes, it should probably be referred to the genus *Idiostroma*, Winch., and should stand as *I. capitatum*, Goldf., sp. Scattered through the tissues in this species, in a large number of specimens, are vesicles

FIG. 8.

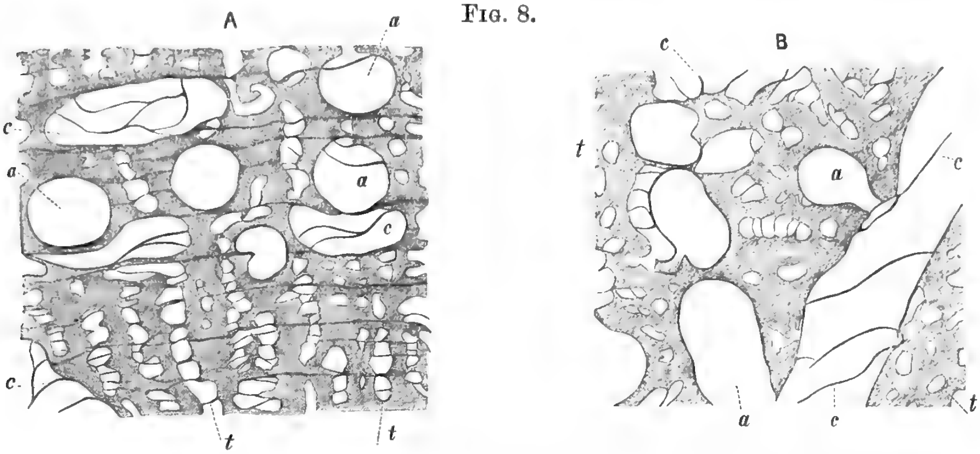


FIG. 8.—A. Vertical section of *Idiostroma capitatum*, Goldf. (?), from the Devonian Rocks of Hebborn (Paffrath district), enlarged twelve times; B. Tangential section, similarly enlarged; *a a*. Supposed "ampullæ;" *c c*. Large tabulate tubes; *t t*. The ordinary zoöidal tubes.

(Fig. 8) of a lenticular, oval, spherical, or elongated shape, which are bounded principally by the general skeletal tissue, and commonly have no proper wall of their own. These are mostly about 1 mm. in diameter, less or more; and they are occasionally crossed by one or more calcareous partitions or tabulæ. Sometimes they appear to be appended to the sides of the large tabulate canals which traverse the skeleton in this type; but at other times they seem to have no connection with these. They occur, as might be expected, at all depths below the surface, since the species is one which grows by the formation of successively superimposed laminæ, and each successive layer constitutes therefore in its turn the actual surface.

I have not recognised these curious structures with any certainty, or in any conspicuous form, in any other Stromatoporoid except the one just mentioned; but it is quite possible that they will be found in others if carefully looked for. In the particular type above alluded to, thin sections prove conclusively that these vesicles are really parts of the organism in which they are found, and are not

adventitious or imbedded structures of any kind. It is necessarily impossible to speak with certainty as to their nature; but the most probable hypothesis seems to be that which would regard them as having lodged the reproductive zoöids, and as corresponding with the "ampullæ" of the *Stylasteridæ* and of *Millepora Murrayi*, Quelch. It may, further, be conjectured, with some probability, that the axial tubes of the cylindrical types of *Idiostroma* (Pl. IX, figs. 6, 7, 8), as also of *Stachyodes* (Pl. VIII, fig. 10), with their lateral tabulate offshoots, were connected with the development of the reproductive zoöids.

III. SYSTEMATIC POSITION AND AFFINITIES.

The Stromatoporoids have been referred by different naturalists to very different groups in the animal kingdom, but most generally to one or other of the four divisions of the Sponges, to the *Foraminifera*, the Corals, or the *Hydrozoa*. We may, therefore, speaking roughly, say that they have been generally regarded either as Rhizopods or Cœlenterates. The former view is the one which, with some reservations, I have myself held, being influenced in so doing principally by the fact that no observer had succeeded in demonstrating in any Stromatoporoid (excluding the problematical forms grouped under *Caunopora*, Phill.) the existence of any tubes or cells which might have been supposed to have served for the lodgment of the zoöids of a Cœlenterate colony. My own researches, however, have now led me to recognise the presence of such unquestionable zoöidal tubes (as previously described) in various typical Stromatoporoids, and I am therefore, now able to frankly accept the views of Carter, Lindström, Steinmann, Zittel, Bargatzky, and other well-known observers, as to their Cœlenterate affinities. I am also quite satisfied that the Stromatoporoids belong to the *Hydrozoa* and not to the *Actinozoa*, and that they have relationships with both *Hydractinia* on the one hand and *Millepora* on the other hand, though I regard them as quite distinct from either of these genera, and as forming a special group of the *Hydrozoa*, for which the name of *Stromatoporoidea*, originally proposed by Dr. Murie and myself, may be retained.

In the presence of the large body of evidence which we now have as to the minute structure of the Stromatoporoids, it does not appear to me to be necessary here to discuss in detail the reasons which induced different investigators to refer the Stromatoporoids to the *Foraminifera*,[1] the Sponges, or the Corals. I shall,

[1] From one point of view, the system of minute tubuli which I have been able to show to exist within the skeletal tissue of many Stromatoporoids might, no doubt, be accepted as evidence of Foraminiferal affinities. The value of such evidence is, however, destroyed by the still closer resemblance of the tubuli in question to the minute canaliculi of the skeleton in various of the Hydrocorallines (*e.g. Distichopora* and *Allopora*).

therefore, merely deal briefly with the evidence bearing upon their reference to the *Hydrozoa*, and upon the position in that class which ought to be assigned to them.

The first observer who seems to have suspected the relationship between the Stromatoporoids and the *Hydrozoa* was Dr. Lindström, who pointed out that *Labechia*, E. and H., previously regarded as a "Tabulate" Coral, possessed a skeleton in many respects very similar to that of *Hydractinia*, Van Beneden ('Öfvers. af Kongl. Vetenskaps-Akad. Förh.,' No. 4, 1873, and 'Ann. and Mag. Nat. Hist.,' July, 1876). The next observer who took up this subject was Mr. Carter, who published a series of most valuable papers on the structure of the skeleton of the *Hydractiniidæ* ('Ann. and Mag. Nat. Hist.,' 1877 and 1878), and who maintained that the Stromatoporoids were *Hydrozoa* and related to *Hydractinia* and also to *Millepora*. In 1878 also, Dr. Steinmann published his admirable memoir 'Ueber fossile Hydrozoen' ('Palaeontographica,' n. F., v. 3 (xxv), p. 101), in which he not only referred *Stromatopora* itself to the *Hydrozoa*, but greatly increased our knowledge of various related types. The views advocated by the observers just mentioned have been since adopted by Zittel ('Handbuch der Palaeontologie'), Roemer ('Lethæa Palæozoica'), Bargatzky ('Die Stromatoporen des rheinischen Devons'), and other competent authorities, and may be regarded as now almost universally accepted. This general acceptance of the reference of the Stromatoporoids to the *Hydrozoa* is, perhaps, the more remarkable, when it is considered, as before pointed out, that no demonstration had been effected of proper zoöidal tubes in any of the normal Stromatoporoids. At the present time, therefore, when such tubes can be shown to exist in many forms, there can be little hesitation in admitting the Stromatoporoids to a place in the class of the *Hydrozoa*, though there may be some difference of opinion as to the precise position in this class which they ought to occupy.

In order to determine this last point, if only approximately, it will be necessary to consider more particularly the structure of the skeleton in the two recent genera of *Hydrozoa* which are most nearly related to the Stromatoporoids, viz. *Hydractinia* and *Millepora*.

Hydractinia echinata, Flem., the most readily obtainable type of the genus *Hydractinia*, forms thin horny crusts, which grow upon the exterior of various Gasteropodous shells, but apparently only upon those which are tenanted by Hermit Crabs. In its earliest condition, the skeleton consists of a delicate chitinous pellicle, growing upon some shell, by the maceration of which in weak acid it can be readily obtained for examination. In this stage it consists of numerous nodal points, the so-called "horn-cells" of Carter, united by radiating horizontal processes, or fibres, which coalesce to form an irregular cribriform membrane, for which we may employ Mr. Carter's name of the "basal lamina" (Plate VI, fig. 2). According to Mr. Carter's researches, the "horn-cells" appear first in the substance of the shell as separate

cells, which generate round themselves concentric layers of chitine. In their nature the horn-cells are the primitive "radial pillars," into which they become ultimately converted in old colonies, while the horizontal clathrate fibres represent the first concentric lamina. The interstices of the creeping network are occupied by the cœnosarc, from which the polymorphic zoöids are given forth. Superiorly, the "horn-cells" project upwards as short tubercles, interspersed at intervals with larger serrated spines. Moreover, the primitive lamina may show shallow branching grooves or gutters, the "astrorhizal grooves," which lodged corresponding stolons of the cœnosarc.

If the colony continues to grow, the "horn-cells," or "radial pillars," grow upwards, and when they attain a certain height, throw out irregular horizontal processes or "arms," by the union of which a second cribriform horizontal "lamina" is produced. By a repetition of this process, the colony may at last assume a considerable thickness; but, as a rule, it is only in the neighbourhood of the mouth of the invested shell, where the polypites are most abundantly supplied with food, that more than two or three successive laminæ are produced. In the immediate vicinity of the mouth of the invested shell the colony may grow to a thickness of one line or more, partly by the addition of fresh concentric laminæ, and partly by a simultaneously effected absorbtion of the shell on which it grows. This gradual absorbtion of the invested shell goes on over the whole surface, but much more actively near the mouth of the shell than elsewhere; and hence in old colonies of *Hydractinia echinata* one often finds the calcareous substance of the shell largely, or in parts wholly, replaced by the horny fibres of the investing crust, the shell being also lined internally by a smooth horny layer.

It is to be remembered that this kind of transformation of the shell of a Gasteropodous Mollusc, though commonly the result of the growth of a colony of *Hydractinia,* is also well known to be occasionally produced by investing parasites of quite a different nature. Thus, a similar change is not uncommonly effected by *Suberites domuncula*, Nardo; the Sponge in this case further resembling the colony of *Hydractinia* in the fact that it invariably, so far as I have seen, grows upon a shell which is tenanted by a Hermit-Crab. The same phenomenon is also sometimes the result of the growth of certain of the *Polyzoa.* Thus, colonies of *Cellepora edax,* Busk, one of the Crag *Polyzoa*, produce a similar transformation of the Gasteropodous shell upon which they grow.

I may note, in passing, that, though I have often specially investigated the point, I have never observed any case in which there are indications of a similar transformation of an invested shell or coral as produced by colonies of *Labechia* or of any other Stromatoporoid. On the contrary, the invested body seems always —as shown by thin sections—to retain its original form and its original surface unchanged, the investing Stromatoporoid simply growing upon its exterior.

In order to satisfactorily compare the skeleton of *Hydractinia echinata* with that of a Stromatoporoid, it is best to take the thickened portion of an old colony of *Hydractinia*, where it surrounds the mouth of the invested shell. In this region the shell itself has usually been absorbed, so that decalcification is not needful, and it is easy to make thin sections, both in a vertical and a tangential direction. On looking at the *surface* (Pl. VI, figs. 3, 3, *a*) we see that it is studded with numerous small projecting tubercles, which represent the free upper ends of the "radial pillars." Intermixed with these are numerous larger serrated "spines" (Pl. VI, fig. 6), which are apparently formed by the upward growth of a number of the radial pillars, and by the coalescence of the free ends of these into a loose reticulation. Between the bases of the tubercles and spines may be seen minute circular apertures, which either give exit to polypites, or which serve for the passage of stolons which place the superficial layer of the cœnosarc in connection with the deeper layers of the same. The surface also exhibits the shallow, irregular astrorhizal grooves. The surface-lamina is, therefore, in the main, only a repetition of the "basal lamina," as also of all the laminæ intervening between the first and the last-formed layer. The principal difference is only that the "astrorhizal" grooves have the form of shallow open gutters on the surface of the last-formed lamina, whereas they are necessarily in all the other laminæ more or less completely roofed over, and converted into canals by the growth of each new layer in turn.

Vertical sections of the thickened colony (Pl. VI, fig. 5) show that it is composed of numerous parallel chitinous rods, which are perpendicular to the surface and to the invested base, and which are united at intervals by horizontal horny fibres. The vertical rods are the "radial pillars," produced by the upward growth of the primitive horn-cells; the connecting fibres are the horizontal "arms," which the pillars give out at intervals; and the spaces between these are filled with the cœnosarc, and represent "interlaminar spaces." In *tangential* sections (Pl. VI, fig. 1) we see the cut ends of the transversely-divided radial pillars, in the form of round horny nodes, which are united by the irregular radiating arms which they give out at intervals. Many of the radial pillars run continuously from the basal lamina to the surface, where their free ends project as tubercles or spines; but others do not seem to be continued through more than two or three successive laminæ. Moreover, each lamina, in turn, may give rise to short ascending tubercles or spines, which simply project into the interlaminar space, but do not reach the next lamina above.

Upon the whole, it must be admitted that there is a remarkable similarity between the minute structure of the chitinous skeleton of *Hydractinia echinata* and that of the large calcareous cœnosteum of certain of the Stromatoporoids, more particularly of the genera *Actinostroma*, Nich., and *Labechia*, E. and H.

A similar resemblance, though not so striking, may be found if we take one of those *Hydractiniæ* which produce a calcareous cœnosteum. The only one of these which I have been able to examine by means of thin sections is the *Hydractinia circumvestiens*[1] of the Red Crag and Coralline Crag of Suffolk. In this interesting species the skeleton is calcareous, and forms crusts of considerable thickness growing upon species of *Trophon* or other Gasteropodous shells. Viewed in thin sections by transmitted light, the skeleton appears to be composed of irregular calcareous grains closely fitted together (Plate VI, fig. 13); but I am not able to say whether or not this is the result of secondary alteration. A rough vertical fracture (Plate VI, fig. 7) shows that the skeleton is traversed by numerous irregular vermiculate tubules, which are approximately vertical, and run parallel to one another at little distances. These vertical tubules are interrupted at intervals by irregular chamberlets, placed in roughly horizontal lines, so as to give rise to imperfect "interlaminar spaces," and to confer upon the skeleton an indistinct lamination. The vertical tubules appear to have lodged the polypites, or to have given passage to stolons of the cœnosarc, and they either terminate in the chamberlets above mentioned (which at one time formed successively the surface of the colony), or they terminate above in minute round apertures on the free surface (Plate VI, figs. 8, 9, and 10). Thin vertical sections (Plate VI, fig, 11) show much the same phenomena as rough fractures; but the skeleton is now seen to be traversed at intervals by a series of vertical "radial pillars" of comparatively large size, and of a more or less open and cribriform texture in their central axes. These large pillars are also recognisable in tangential sections (Plate VI, fig. 12), and they terminate on the surface in prominent round tubercles, which, in some instances at any rate, seem to be furnished with distinct central perforations (Plate VI, figs. 9 and 10). In addition to these large and seemingly hollow pillars, the surface shows numerous small imperforate tubercles, together with well-developed branching astrorhizal grooves (Plate VI, figs. 9 and 10).

From the above sketch of the structure of the skeleton in *Hydractinia echinata*, Flem., and *H. circumvestiens*, Wood, it will be seen that these types exhibit marked points of likeness to certain forms of the Stromatoporoids, with, at the same time, equally marked points of dissimilarity. It will also be seen that so far as *H. echinata*, Flem., is concerned, it is only with a particular section of the Stromatoporoids that the likeness is at all very conspicuous. The section to which I refer is that comprising the genera *Actinostroma* and *Clathrodictyon*, and their allies—what may be called the section of the "Hydractinioid" Stromatopo-

[1] *Hydractinia circumvestiens* was described by Searles Wood under the name of *Alcyonidium circumvestiens* ("Catalogue of Zoophytes from the Crag," 'Ann. and Mag. Nat. Hist.,' ser. i, vol. xiii, 1844). I should be disposed to think that it is really identical with the form described at a later date by Dr. Allman, under the name of *H. pliocæna* ('Geol. Mag.,' 1872, p. 337); but I have not had the opportunity of examining the latter.

roids. The structure of the skeleton of these, with its "radial pillars" and their interlacing "arms," is certainly very similar to that of *Hydractinia*. On the other hand, these types differ from *Hydractinia* in the constantly calcareous constitution of the skeleton, in its massive construction, and in the fact that the organism was certainly for the most part not of an "encrusting" habit of growth. The resemblance between the *Labechiidæ* and *Hydractinia echinata* does not appear to me to be nearly so close as it is in the case of the *Actinostromidæ*. At the same time, it must be admitted that the general structure of *Labechia* and its allies is of the "Hydractinioid" type.

So far as *Hydractinia circumvestiens* is concerned, there are the special peculiarities that well-marked zoöidal tubes are present; that the interlaminar spaces are reduced to rows of irregular chamberlets, and that certain of the radial pillars appear to open upon summit-apertures. Upon the whole, therefore, the Stromatoporoids which most nearly resemble *H. circumvestiens* are the true *Stromatoporæ*, and not the *Actinostromata*.

The genus *Stromatopora*, Goldfuss, and the forms allied to this are, however, more nearly related to *Millepora*, Lam., than to the *Hydractiniæ*. This will be evident from the following brief account of the minute structure of the skeleton in *Millepora*, though on this point I need say little, as the cœnosteum of this genus has been fully described by Professor Moseley ('Report on the Scientific Results of the Voyage of H.M.S. "Challenger," vol. ii, 1881). In connection with the present inquiry I have prepared a tolerably large number of thin sections of various species of *Millepora* for comparison with corresponding sections of the Stromatoporoids, but I have nothing of importance to add to Professor Moseley's description. The skeleton of *Millepora*, as regards its main mass, is essentially composed of a complex network of anastomosing calcareous fibres, so disposed as to give rise to a correspondingly complex network of anastomosing and tortuous canals (Fig. 9, *c c*). In the living condition, this canal-system (Plate IV, fig. 5) is filled with anastomosing stolons of the cœnosarc. According to Professor Moseley, "the canals form regular branching systems, with main trunks which give off numerous branches, from which arise secondary branches, and from these again smaller ramifications. The whole canal-system is connected together by a freely anastomosing meshwork of smaller vessels, and communicates freely by numerous offsets with the cavities of the pores."

The general spongy skeleton, constituted as above described, is traversed at intervals by the vertical tubes in which the zoöids were contained. These are in two series, differing slightly in size according as they contained "gastrozoöids" or "dactylozoöids." The "gastropores" and "dactylopores" may be irregularly distributed, or the dactylopores may be arranged in more or less definite systems round the gastropores. Whatever may be the nature of the zoöids contained in

them, the tubes are intersected by distinct tabulæ (Fig. 9, B), and the skeleton itself shows a more or less conspicuous composition out of thin concentric laminæ, only the thin surface-layer being at any given moment actually alive. Lastly, Mr. Quelch has recently described the reproductive organs of a new species of *Mille-*

FIG. 9.

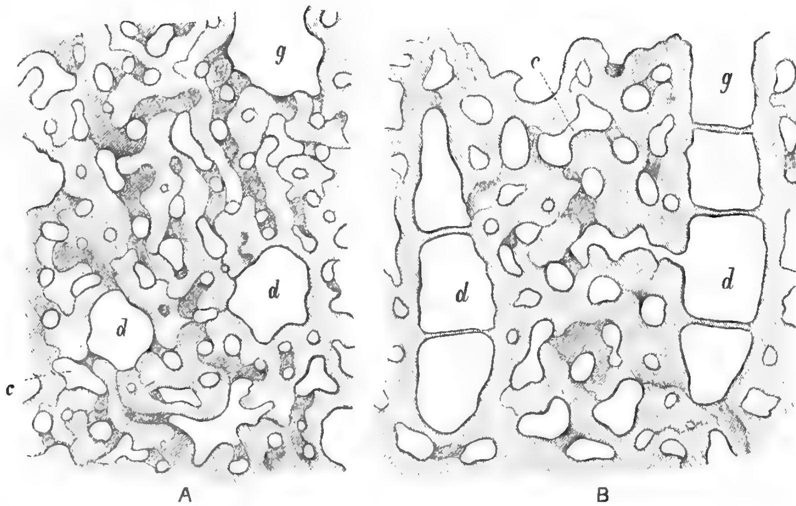


FIG. 9.—Thin sections of *Millepora*, sp., enlarged about thirty-five times. A. Tangential section. B. Vertical section. *g g.* Gastropores; *d d.* Dactylopores; *c c.* Cœnosarcal canals.

pora (*M. Murrayi*), as having the form of circular cavities or "ampullæ," contained within the reticulated spongy skeleton, and covered superficially by a thin porous layer which is often broken away ('Nature,' October 2nd, 1884). In the other species of *Millepora* the reproductive organs have not hitherto been detected; but the above discovery is sufficient to confirm the relationship between the *Milleporidæ* and the *Stylasteridæ*, which had been previously established by the researches of Professor Moseley.

It will be seen from the above brief description of the structure of the skeleton in *Millepora*, that there is a considerable resemblance between it and the skeleton of certain of the Stromatoporoids. This is most conspicuously exhibited when we compare with *Millepora* the forms which constitute the genus *Stromatopora*, Goldfuss. Thus, in the typical *Stromatoporæ*, such as *S. concentrica*, Goldf. (Plate XI, figs. 16 and 18), or *S. typica*, Rosen. (Plate V, figs. 14 and 15), or *S. Hüpschii*, Barg., sp. (Fig. 6), the skeleton is composed of a trabecular calcareous network, traversed by vertical zoöidal tubes, which are placed in communication by means of numerous ramifying cœnosarcal canals. Moreover, the zoöidal tubes are provided with transverse "tabulæ" as they are in *Millepora*. The principal distinctions, in fact, between the skeleton of such types and that of *Millepora* are that the zoöidal tubes of the former are not, as a rule at any rate, divided into two distinct series

("gastropores" and "dactylopores"), while their skeleton-fibre has a peculiar minutely porous structure. Moreover, in various forms of *Stromatopora* we can demonstrate, more or less clearly, the existence of the "radial pillars," which are such characteristic structures in the Stromatoporoids generally.

If, lastly, we turn to the group of the *Stylasteridæ*, as exemplified by such a type as *Distichopora*, Lam., we find, again, certain likenesses to the Stromatoporoids as well as certain marked differences. In *Distichopora* the zoöidal tubes are divisible, as they are in *Millepora*, into two distinct series ("gastropores" and "dactylopores") which occupy definite tracts of the cœnosteum. The general skeleton is composed of dense calcareous tissue, excavated in every direction by branched and anastomosing, microscopic cœnosarcal canals (Plate IV, fig. 4, and Plate IX, fig. 5). Lastly, in the species I have examined, I find that the pore-tubes are traversed by sparsely-developed, complete, transverse partitions or "tabulæ," which seem, however, to be confined to the deeper portions of the zoöidal tubes, and to disappear as the surface is approached.

There are, unquestionably, strong points of resemblance between such a Stylasterid as *Distichopora* and such Stromatoporoids as *Stachyodes*, Barg. In this latter genus (Plate VIII, figs. 9—14), the cœnosteum is dendroid; there are zoöidal tubes, which open by definite apertures upon the surface (though only doubtfully divisible into two distinct series); and the general tissue of the skeleton is traversed by innumerable microscopic tubuli. The genus *Stachyodes*, however, is an aberrant type, and with regard to the more normal Stromatoporoids we may in the meanwhile leave the Stylasterids comparatively out of view, as apparently further removed from these ancient *Hydrozoa* than either the *Hydractiniæ* or the *Milleporæ*.

Upon the whole, therefore, it would appear that certain of the Stromatoporoids (such as *Actinostroma*, Nich., and *Labechia*, E. and H.) have a skeleton in many respects resembling that of the *Hydractiniidæ;* while others (such as *Stromatopora*, Goldf.) possess hard structures which are more closely comparable with the cœnosteum of *Millepora*. As, however, these two groups of Stromatoporoids are linked together by various intermediate forms (*Clathrodictyon*, *Stromatoporella*, &c.), and as the natural series thus constituted possesses an aggregate of characters distinct from those of either the *Hydractiniidæ* or the *Milleporidæ*, it would not accord with the principles of sound classification to merge the former in either of the last-named divisions of the *Hydrozoa*. I shall, therefore, retain the name of *Stromatoporoidea* for the whole group of organisms now under consideration, regarding them as a peculiar division of the *Hydrozoa*, with affinities to the *Hydractiniidæ* on the one side and to the *Hydrocorallinæ* on the other side. The propriety of thus keeping the Stromatoporoids as a separate group is the more evident when it is remembered that our knowledge of these singular organisms is necessarily derived

from an examination of their hard parts alone. Could we examine them in the living condition, it is not impossible that we should find that the differences which separate them from either *Hydractinia* or *Millepora* are greater than those which separate the animal of the former of these recent genera from that of the latter.

IV. SKETCH-CLASSIFICATION.

In the present state of our knowledge it is probably impossible to give any classification of the Stromatoporoids which can claim to have a more than provisional value. Many forms are still imperfectly known; while others have been described from their external characters only, and cannot, therefore, be at present placed in any system of classification based upon the minute structure of the skeleton. Considering, however, that we can never have any positive knowledge as to the nature of the soft parts in the Stromatoporoids, it is clear that the foundation of any sound classification must be sought for in the construction of the skeleton, and all modern observers will admit that a satisfactory acquaintance with this can only be acquired by the help of the microscope and through the medium of properly prepared thin sections. When we have obtained a definite knowledge of the minute structure of the skeleton, we can usually correlate this with certain external characters, and it thus becomes possible to recognise many species of Stromatoporoids by superficial peculiarities alone. Under the best of circumstances, however, there are always many specimens so badly preserved as regards their superficial characters, that even a practised observer would fail to identify them without the help of microscopic slides. Moreover, as has been already pointed out, there are many specimens in which even the microscope ceases to be of much service in their determination, owing to the fact that the internal structure of the skeleton has been more or less altered during the process of fossilisation. Many of the Stromatoporoids from the Wenlock Limestone of Gotland are in this condition, and this is occasionally the case with the specimens from the Wenlock Limestone of Britain. I find a similar change to have affected most of the Stromatoporoids which have been collected by Mrs. Robert Gray from the Silurian Rocks of the Girvan area, and which she has been good enough to confide to me for examination. In other cases, again, a long series of specimens may be examined, and perhaps not more than one or two examples will be found in which the internal structure is satisfactorily preserved.

In view of the above-mentioned difficulties which attend the study of the Stromatoporoids, and bearing in mind that there are yet various described types

which have still to be examined by modern methods, the following classification must be regarded as largely tentative, though I think it will be found to indicate the lines upon which any future classification must be based. Students of recent forms may be inclined to consider the number of families proposed as out of all proportion to the number of genera. It should be remembered in this connection, however, that many more generic types almost certainly remain to be yet discovered, and that the forms at present known are in all probability only the widely separated links of a great series of extinct *Hydrozoa*, of which our knowledge is at present very imperfect. I shall subsequently discuss the characters of the families and genera at some length; but it may be as well, at the risk of some repetition, to subjoin here a brief tabular view of the classification which I have ventured to suggest.

ORDER—STROMATOPOROIDEA, *Nich. and Mur.*

Hydroid Zoophytes producing a calcareous cœnosteum, which may be encrusting or dendroid; but which is most commonly laminar or massive, with a basal epitheca, and a comparatively small peduncle of attachment. Cœnosteum composed essentially of two sets of elements, viz.: (1) hollow or solid calcareous rods, or pillars, which are "radial" in position, or are vertical to the general surface; and (2) hollow or solid calcareous fibres or plates, which are in the main rectangular to the preceding, or "tangential" to the general surface, and which are developed at more or less definite intervals, thus giving rise to a series of horizontal "laminæ." The radial pillars may be much modified, or even partially suppressed as definite structures. Very generally the horizontal fibres are more or less closely united with one another and with the radial pillars, and thus give rise to a reticulated skeleton.

The skeleton-fibre may be apparently solid, but in other cases is minutely porous or tubulated.

Definite zoöidal tubes may be present or absent. When present, they are usually "tabulate," and appear in general to be approximately similar to one another in size and internal structure.

"Astrorhizal canals" may be present, or absent. [No account is taken of the so-called "*Caunoporæ*" in the above definition, as the nature of the fossils so named will be dealt with separately.]

SECTION A ("Hydractinioid" Group).

Fam. 1. ACTINOSTROMIDÆ, *Nich.*

Skeleton composed of distinct radial pillars which give off horizontal processes, these latter having a radiating arrangement, and inosculating with one another in such a manner as to give rise to a "rectilinear" meshwork. Radial pillars confined to the separate interlaminar spaces, or passing continuously through many successive laminæ. Definite zoöidal tubes are wanting, or are very imperfectly developed.

Genera.—*Actinostroma*, Nich.; *Clathrodictyon*, Nich. and Mur.; *Stylodictyon*, Nich. and Mur. (?).

Fam. 2. LABECHIIDÆ, *Nich.*

Cœnosteum usually laminar or massive, with a basal epitheca; sometimes cylindrical. Skeleton composed of curved or horizontal calcareous plates, arranged so as to constitute a stratified vesicular tissue, but not giving rise to concentric "laminæ." Radial pillars sometimes well developed and "continuous," at other times rudimentary. Definite zoöidal tubes not developed.

Genera.—*Labechia*, E. and H.; *Rosenella*, Nich.; *Beatricea*, Bill. (?); *Dictyostroma*, Nich. (?).

SECTION B ("Milleporoid" Group).

Fam. 3. STROMATOPORIDÆ, *Nich.*

Cœnosteum having the radial and horizontal elements so combined with one another as to give rise to a more or less continuously reticulated skeleton. Skeleton-fibre minutely porous or tubulated. Definite zoöidal tubes furnished with "tabulæ" are developed.

Genera.—*Stromatopora*, Goldf.; *Stromatoporella*, Nich.; *Parallelopora*, Barg. (sub-genus?); *Syringostroma*, Nich. (sub-genus ?).

Fam. 4. IDIOSTROMIDÆ, *Nich.*

Cœnosteum usually cylindrical, often branched and dendroid, with a principal "axial tube," which is intersected by tabulæ and gives off lateral tabulate branches. Definite zoöidal tubes are present. The general tissue of the skeleton is continuously reticulated, and the skeleton-fibre is mostly porous or tubulated.

Genera.— *Idiostroma*, Winch.; *Hermatostroma*, Nich. *Amphipora*, Schulz; *Stachyodes*, Barg.

V. FAMILIES AND GENERA OF THE STROMATOPOROIDS.

Fam. 1. Actinostromidæ, *Nich.*

Skeleton composed of distinct "radial pillars," which give rise to concentrically disposed "laminæ," by the production at successive levels of horizontal processes or "arms," which inosculate to form a "rectilinear" meshwork.

In this family I include those Stromatoporoids in which the cœnosteum is clearly composed of radial pillars and concentric laminæ, the latter formed by the anastomosis of radiating calcareous fibres, in such a manner as to give rise to a loose network, the meshes of which are typically angular. The skeleton is not a continuously reticulated one, and therefore in this family, unlike what occurs in the *Stromatoporidæ*, the radial pillars are always recognisable in tangential sections as distinct from the horizontal processes to which they give rise. The skeleton-fibre is not minutely porous, and the radial pillars are often hollow internally. Definite zoöidal tubes, as distinct from the angular meshes formed by the inosculating horizontal processes, are not present. The surface is granulated or tuberculated by the projecting upper ends of the radial pillars. Astrorhizæ may be present or absent. The form of the cœnosteum is exceedingly variable, an epitheca being sometimes present, sometimes absent.

Genus Actinostroma, *Gen. nov.*

(= *Stromatopora*, auctt.).

Radial pillars "continuous," *i.e.* passing continuously through a number of laminæ and interlaminar spaces. When the laminæ are grouped into "latilaminæ," as is not uncommonly the case, the radial pillars are continued from the under surface of each latilamina to the upper surface. The horizontal processes or "arms" are delicate, solid or hollow fibres, which are given off from the radial pillars in whorls, at corresponding levels, and which unite to form an angular meshwork. Astrorhizæ may be present or absent.

Owing to the discovery that the original specimen of *Stromatopora concentrica*, Goldf., possesses a continuously reticulate skeleton of the "Milleporoid" type, I have been compelled to propose the new generic name of *Actinostroma* for those widely-spread Stromatoporoids which had up till now been generally regarded as referable to the genus *Stromatopora*, Goldf. The species, which has been generally

identified as *Stromatopora concentrica*, Goldf., I shall name *A. clathratum.* It is an abundant form in the Devonian formation of both Britain and Germany, but I have not recognised its existence hitherto in the Devonian of North America. In the Devonian formation there occur several other types, more or less closely related

Fig. 10.

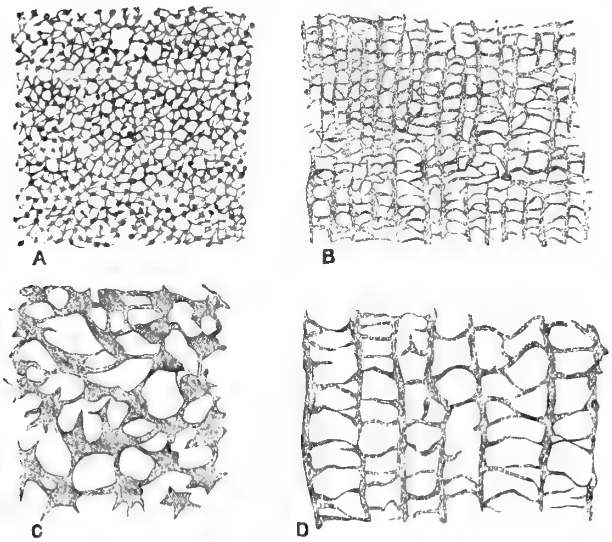


Fig. 10.—Minute structure of *Actinostroma intertextum*, n. sp., from the Wenlock Limestone, Benthall Edge. A and B. Tangential and vertical sections, enlarged twelve times. C and D. Parts of the same, enlarged twenty-four times.

to *A. clathratum.* One of these is the form to which Goldfuss gave the name of *Ceriopora verrucosa*, and which will now stand, therefore, as *Actinostroma verrucosum.* Another is the common Devonian species which Bargatzky described under the name of *Stromatopora astroïtes*, Rosen; the latter being really a true *Stromatopora.* I shall describe this later as *Actinostroma stellulatum.* A third form, which, like the preceding, is found in the Devonian deposits of both Britain and Germany, is remarkable for the possession of two distinct series of radial pillars, one of large size and the other small; and I shall name this *Actinostroma bifarium.* The only Silurian species of the genus with which I am at present acquainted are the singular *A.* (*Stromatopora*) *Schmidtii*, Rosen, and a new form (*A. intertextum*, Fig. 10) from the Wenlock Limestone of Britain.

The essential character which distinguishes *Actinostroma* from the genus *Clathrodictyon* is the continuity of the radial pillars in the former. As no vertical section can possibly be prepared, which shall run precisely along the axis of any single radial pillar, or of any set of pillars, throughout its entire length, it is not possible to ascertain precisely the extent to which this continuity of the radial pillars is carried. A single radial pillar may often be followed through ten, fifteen, twenty, or more laminæ and successive interlaminar spaces; and I am of opinion

that they really run continuously for considerably greater distances. In *A. clathratum*, in which the cœnosteum commonly grows in "latilaminæ," the pillars seem certainly to extend in general through the entire thickness of a latilamina. The radial pillars are mostly, perhaps always, hollow, each being traversed by a minute and apparently often nearly obliterated axial canal (Pl. I, figs. 10 and 13). This phenomenon can only be recognised in tangential sections, and only in well-preserved specimens. On the free surface of the cœnosteum, the pillars terminate in blunt and apparently imperforate tubercles (Pl. II, fig. 11).

Tangential sections (Pl. I, figs. 8, 10, 11) show the cut ends of the radial pillars and the angular meshwork formed by the inosculation of the horizontal connecting-processes; the structure being of what has been called the "hexactinellid type," from its superficial resemblance to the spicular network of some of the Hexactinellid Sponges.

So far as my observations have extended, astrorhizæ are present in the majority of species belonging to the genus *Actinostroma*, including the type-species *A. clathratum* (= *S. concentrica*, Barg.) in which their existence has been denied. They vary, however, greatly in their development, and they are apparently occasionally wanting. In at least one species of the genus (namely, that which Bargatzky has erroneously identified with *Stromatopora astroites*, Rosen) they are largely developed, and are arranged in successive superposed groups, connected by vertical wall-less canals (Pl. IV, fig. 3, *a*).

The form of the cœnosteum in the genus *Actinostroma* is usually massive or laminar, and in the latter case an epitheca is almost always developed basally. In the massive forms, however, the colony often grows in successive layers, of which the first is attached to some foreign body.

Genus Clathrodictyon, *Nich. and Mur.*

('Journ. Linn. Soc.,' vol. xiv, p. 220, 1878.)

Cœnosteum often of large size, usually expanded or laminar, with a concentrically-wrinkled basal epitheca and a small base of attachment; occasionally massive. The general structure of the skeleton is like that of *Actinostroma*, but the radial pillars are incomplete, and are never "continuous." Astrorhizæ are present. The surface is minutely granular or vermiculate, without marked prominences or "mamelons."

In certain of the types which may be placed under *Clathrodictyon*, such as *C. regulare*, Rosen, the general structure of the skeleton is precisely that of *Actinostroma*, except that the radial pillars are confined strictly to the interlaminar spaces in which they take their origin, and never pass continuously through suc-

cessive laminæ and interlaminar spaces. The result of this is to give to vertical sections (Pl. II, fig. 8, and Pl. V, fig. 1) a singularly regular aspect, as formed of rectangular spaces arranged in successive tiers one above the other. Tangential sections (Pl. V, fig. 2) show the cut ends of the short radial pillars, and in the centre of these one may sometimes observe traces of the existence of a minute central cavity. The last-formed pillars terminate superficially in minute, apparently imperforate tubercles (Pl. II, fig. 12).

In the more characteristic species of *Clathrodictyon*, including the type-species, *C. vesiculosum*, Nich. and Mur., not only are the radial pillars incomplete, in the sense that many of them simply project for a short distance into the interlaminar space in which they are developed, but in many cases they cease to a greater or less extent to exist as independent structures. Not only do the radial pillars become very irregular, but the horizontal processes which form the concentric laminæ are equally irregular; and the two sets of structures are so united together as to give rise to a tissue of larger or smaller lenticular vesicles. Hence in vertical

FIG. 11.

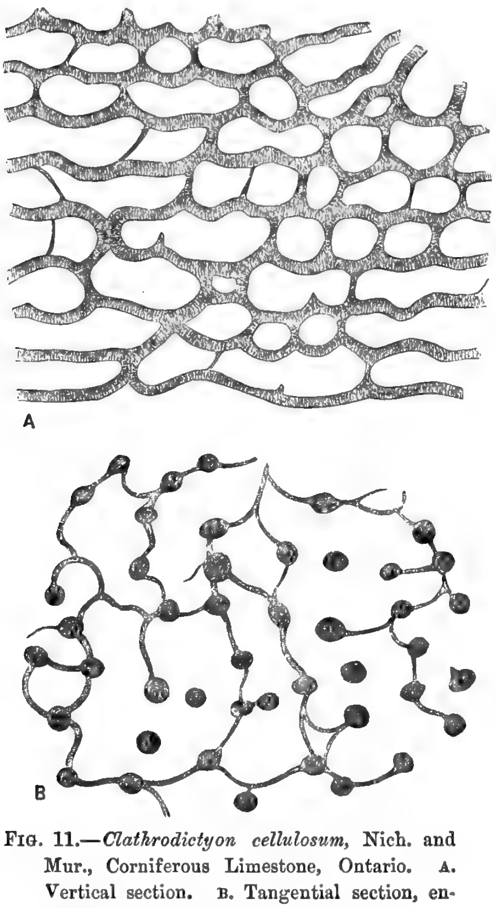


FIG. 11.—*Clathrodictyon cellulosum*, Nich. and Mur., Corniferous Limestone, Ontario. A. Vertical section. B. Tangential section, enlarged twelve times.

FIG. 12.

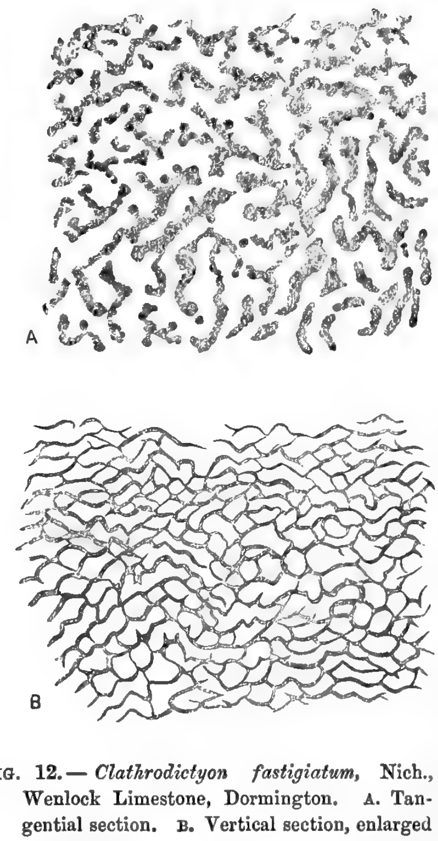


FIG. 12.—*Clathrodictyon fastigiatum*, Nich., Wenlock Limestone, Dormington. A. Tangential section. B. Vertical section, enlarged twelve times.

sections (Figs. 11 and 12, and Plate V, figs. 1, 3, 5, 6) the general aspect of the structure resembles that of the vesicular tissue of a *Cystiphyllum* or the so-called "cœnenchymal" tissue of such corals as *Plasmopora* or *Fistulipora*. Tangential sections (Plate V, figs. 2, 4, 7) show a somewhat similar reticular structure, sometimes vermiculate, and generally more or less clearly exhibiting the cut ends of a number of the radial pillars.

Astrorhizæ are generally present. The surface is either minutely granular, or is covered with vermiculate ridges (Plate II, figs. 12 and 13); but there are no conical elevations or "mamelons."

With the exception of *C. cellulosum*, Nich. and Mur., from the Corniferous Limestone of Canada (Fig. 11), and of an undescribed form from the Devonian Limestones of South Devon (from the collection of Mr. Champernowne), I am not acquainted with any Devonian species of *Clathrodictyon*. On the other hand, the genus is largely represented in the Upper Silurian rocks. The type-species is the *C. vesiculosum*, Nich. and Mur., of the Clinton and Niagara formation of North America (Plate V, fig. 5). A very nearly allied type is the *C. variolare*, Rosen, sp. (Plate V, fig. 6), of the Wenlock Limestone of Esthonia and of Britain. Another very beautiful species is *C. striatellum*, D'Orb. sp. (Plate V, figs. 3 and 4), which is characteristic of the Wenlock Limestone of Britain, but occurs also in the Ordovician Rocks of Esthonia, whence it was described by Friedrich Schmidt under the name of *Stromatopora mammillata*. Other Wenlock species of the genus are *C. regulare*, Rosen, sp. (Plate V, figs 1 and 2), and *C. fastigiatum*, n. sp. (Fig. 12).

Genus STYLODICTYON, *Nich. and Mur.*

('Journ. Linn. Soc.,' vol. xiv, p. 221, 1878).

Cœnosteum massive, traversed by numerous closely-set circular vertical columns of large size, which are formed by the upward bending of the concentric laminæ, and which terminate on the surface in small pointed eminences (Plate VII, figs. 7, 8, 9). Each of these vertical columns is composed of a dense central axis surrounded by a zone of thickened reticulated tissue. The intercolumnar spaces (Plate VII, figs. 10 and 11) are occupied by the general tissue of the skeleton, composed of concentric laminæ and radial pillars, and much resembling the skeletal tissue in the genus *Clathrodictyon*. The radial pillars are imperfectly developed, not being "continuous," and commonly falling short of the lamina next above that from which they take their origin. The concentric laminæ are well developed, being curved in each intercolumnar space, with their convexities downwards, and bent upwards sharply as they join the "columns" on both sides. The laminæ have further a kind of alternate arrangement in groups, those of one group being

very close together, with few or no radial pillars in the interlaminar spaces; while those of the next group are further apart, and have their interlaminar spaces crossed by short irregular pillars. Extremely well-developed astrorhizæ are present.

This genus was founded by Dr. Murie and myself (*loc. cit.*) for the singular *S. columnare* (=*Stromatopora Wortheni*, Quenst.), first described by me from the Devonian Rocks of North America ('Pal. of Ohio,' vol. ii, p. 253, Plate XXIV, fig. 1). We included in the genus another form (viz. *S. retiforme*, Nich. and Mur.), but this is in reality a species of *Actinostroma*, and is nearly related to *A. verrucosum*, Goldf., sp. On the other hand, *Stylodictyon columnare*, Nich., is a very peculiar type, and in the present state of our knowledge can hardly be referred to any other genus. I am not, however, clear as to the position which the genus *Stylodictyon* ought properly to occupy, as the characters of the type-species are in many respects such as would give it an intermediate place between the *Actinostromidæ* and the *Stromatoporidæ*. In vertical sections, the structure of the skeleton—apart from the characteristic columns—conforms to that of the *Actinostromidæ*, the concentric laminæ being very well developed, and the radial pillars not being obliterated. On the other hand, tangential sections (Plate VII, fig. 10) do not show the cut ends of the pillars, but rather show a reticulated tissue, similar to that of the *Stromatoporidæ*.

Various Stromatoporoids show an approach to the structure of *Stylodictyon columnare* as regards the peculiar vertical columns which intersect the entire cœnosteum. *Stromatopora consors*, Quenst., is an example in point. Much more extended researches are, however, necessary before it can be asserted that the structure of the forms in question is really the same as in the present genus, or before we can deal more precisely with the type-species, *S. columnare*.

The columns of *Stylodictyon* may, perhaps, be compared with the large spines of *Hydractinia circumvestiens*, S. V. Wood (Plate VI, figs. 11 and 12); but they appear to be rendered quite solid centrally, by the complete obliteration of the interlaminar spaces, and they do not, therefore, open by apertures on the surface.

Fam. 2, LABECHIIDÆ, *Nich.*

The cœnosteum in this family is composed of large-sized calcareous vesicles, which are usually lenticular in shape, but may be rectangular, and which are arranged in superposed strata as regards either a basal plane or an axial tube. The vesicles are traversed at intervals by "radial pillars" directed at right angles to the plane of their strata; or they carry the same structures in a rudimentary

form upon their upper convex surfaces. The external surface usually exhibits larger or smaller tubercles, representing the upper ends of the radial pillars. No astrorhizæ are present. A basal epitheca is often present. No definitely circumscribed zoöidal tubes appear to exist. The skeletal tissue is mostly apparently compact or granular; but its minute structure has at present been imperfectly investigated. [The radial pillars of *Labechia conferta* appear to have a peculiar cribriform structure, apart from their possession of axial canals.]

It would be easy to give a satisfactory definition of this family, if we were to include in it only the various species of *Labechia*, E. and H. It is, however, impossible in the present state of our knowledge to frame a sufficient diagnosis of the family, if we include in it, as we seemingly must do, not only the singular *Rosenella dentata*, Rosen, sp., and its allies, but also the still more aberrant types included by Billings under the name of *Beatricea*. As a merely provisional arrangement, we may also place in this family the very incompletely known genus *Dictyostroma*, Nich.

Genus Labechia, *Edwards and Haime.*

(' Polyp. Foss. des Terr. Paléoz.,' p. 279, 1851.)

The skeleton in this genus is laminar or massive, usually furnished with a concentrically wrinkled basal epitheca (Plate III, fig. 7), and attached by a small peduncle, and not genuinely encrusting, though often involving foreign bodies in its growth. Very young examples (Plate III, figs. 9—11) consist of a flattened circular basal epitheca supporting a single layer of blunt tubercles on the upper surface. Adult examples have these tubercles developed into stout radial pillars, which are continued through the thickness of the cœnosteum without a break, and terminate on the upper surface in blunt and apparently imperforate tubercles. The radial pillars contain a distinct axial canal, but they would seem to be solid at their apices. They run parallel to one another, and are united by curved or straight calcareous plates which form a series of large-sized vesicles, filling up all the interspaces between the pillars. Owing to the entirely irregular development of these vesicles, the cœnosteum shows no tendency to split concentrically, as is observed in the normal Stromatoporoids, and there are no definite " concentric laminæ."

The skeleton in the genus *Labechia*, E. and H., has in the main a resemblance to that of *Actinostroma*, Nich., but it differs from this in the great size of the radial pillars, and in the fact that the horizontal processes which are developed from these appear to have the form of convex or flat plates, instead of mere fibres, while they are produced with such irregularity as not to give rise to distinct " laminæ." The radial pillars are undoubtedly hollow, and contain an axial canal

(Fig. 13), which may in some cases be even transversely partitioned (e.g. in *L. serotina*, n. sp. Fig. 4). The axial canals are surrounded by denser tissue arranged in

FIG. 13.

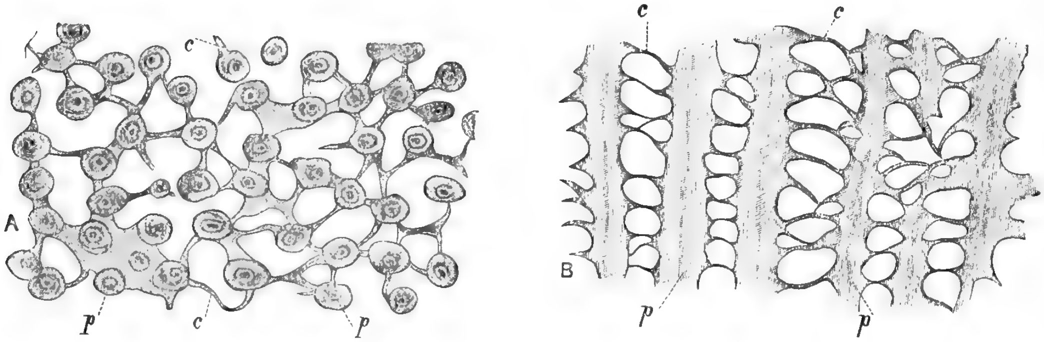


FIG. 13.—Sections of *Labechia conferta*, Lonsd., enlarged twelve times. Wenlock Limestone, Benthall. A. Tangential section. B. Vertical section. *p p*. Radial pillars. *c c*. Tabular connecting-processes.

concentric layers, but exhibiting distinct vacuities, and thus not strictly solid. The superficial terminations of the pillars are for the most part apparently solid. If, however, the tissue of the pillars be really cribriform, as there seems reason to believe, then this apparent solidity may be only due to the fact that any superficial pores are filled with the matrix. Sometimes the surface tubercles clearly show at their summits a minute pit, representing the upper end of an axial canal (Plate III, fig. 14), but no traces of such openings can be detected in other examples (Plate III, fig. 15), and it is not impossible that the appearance of perforations may be really the result of weathering.

Dr. Gustav Lindström and Professor Ferdinand Roemer have given descriptions of the structure of *Labechia*, which differ in important respects from that given above. The former of these distinguished observers has described the cœnosteum of *Labechia* as consisting in its earliest stages of growth "of a very thin circular disc, with concentric lines of growth beneath, and having the superior surface studded with blunt spines, which radiate from the centre, and also coalesce and form continuous ridges. . . . . During the course of growth the primitive disc of *Labechia* is increased in thickness by the addition of successive thin strata, which closely conform to the subjacent fundamental crust, being elevated where the spines are situated. As these successive layers leave a small space between them and are in themselves very thin, they give rise to a false appearance of tabulæ" ('Ann. and Mag. Nat. Hist.,' ser. 4, vol. xviii, p. 4, 1876). Prof. Ferd. Roemer ('Lethæa Palæozoica,' p. 543, 1883) describes the skeleton of *Labechia* as consisting wholly of very thin horizontal lamellæ, which are superimposed one above the other in a continuous series, all being in practically direct contact with one another, and being bent into a system of close-set conical elevations, which in the last-formed layer give rise to the surface-tubercles. According to this view there are

in *Labechia* *no* radial pillars, *no* interlaminar spaces, and, of necessity, none of the vesicular tissue which I have described as filling all the spaces between the radial pillars.

It is, however, quite beyond question that the skeleton of the English examples of *Labechia conferta* consists essentially of radial pillars and intervening vesicular tissue, as above described. Some specimens of the same species which Dr. Lindström was good enough to send me from the Wenlock Limestone of Gotland, exhibited this structure quite as clearly as our British examples, and I was, therefore, at first much puzzled with the discrepancy between the phenomena observed in these and the descriptions given by Lindström and Roemer. Professor Roemer was, however, so kind as to send me a specimen and slide of the form which had served as the basis of his description of the structure of *Labechia conferta*, Lonsd., and which, as coming from Gotland, may be supposed to agree with those that had been under observation by Dr. Lindström; and an examination of this explained the discrepancy in question. The specimen, namely, apparently belonged to *Labechia conferta*, Lonsd., and, indeed, exhibited a very well-preserved surface; but the internal structure had been almost wholly destroyed by a process of secondary crystallisation—a phenomenon which is not uncommonly observable in other Stromatoporoids. Hence the radial pillars and intervening lenticular vesicles, which are quite well preserved in certain of the Gotland specimens, had been wholly obliterated, and the observable structure was simply that of a series of undulated and closely superimposed layers, as described by Dr. Lindström and by Professor Roemer. Recently, moreover, I have collected a number of examples of *Labechia* from the Upper Oesel Group (Ludlow formation) of Esthonia, which are in a precisely similar condition of internal crystallisation, and show precisely similar phenomena. Whether these examples are *specifically* identical with *L. conferta*, Lonsd., or belong to a distinct species, is a matter for further investigation.

The type-species of the genus *Labechia* is the well-known *L. conferta*, Lonsd., of the Wenlock Limestone. Another very interesting type, which I shall subsequently describe under the name of *L. alveolaris*, occurs in the Wenlock Limestone of Britain. In the Devonian Limestone of Devonshire occurs another highly remarkable form, which will be described as *L. serotina* (Fig. 4). The genus has not hitherto been detected in the Ordovician (Lower Silurian) Rocks of either Britain or Europe. At least two species, however, occur in rocks of this age in North America, viz. *L. Canadensis*, Nich. and Mur., of the Trenton Limestone (Plate II, fig. 3), and *L. Ohioensis*, n. sp., from the Cincinnati group of Ohio (Plate II, figs. 1 and 2). The former of these types was taken by Dr. Murie and myself as probably representing the ill-defined genus *Stromatocerium*, Hall ('Pal. N. Y.,' vol. i, p. 48), and we based upon a microscopic investigation of its structure an amended definition of this genus ('Journ. Linn. Soc.,' vol. xiv, p. 222). Further

investigation has, however, shown, as previously pointed out, that the specimens which we had under examination were "reversed," the skeleton being replaced by calcite. When viewed from this aspect, it becomes at once evident that *Stromatocerium canadense*, Nich. and Mur., is really a *Labechia*. The genus *Stromatocerium*, Hall, must therefore be in the meanwhile kept *in retentis*, until a sufficient investigation shall have been made into the minute structure of the original specimens which Professor Hall had under his observation.

Genus ROSENELLA, *gen. nov.*

Cœnosteum laminar or massive, with a basal epitheca. Skeleton composed of slightly curved or undulated calcareous plates, which are so combined as to give rise to a series of comparatively large, elongated, lenticular vesicles, upon the convex upper surfaces of which are carried numerous short and rudimentary radial pillars. The radial pillars mostly fall short of the under surface of the lamina next above that from which they spring, and therefore appear merely as conical tubercles on the upper surfaces of the vesicular plates. Definite zoöidal tubes are not developed; but the laminæ are porous; and when the laminæ are very thick (as they sometimes are) the pores become converted into vertical tubes, which doubtless lodged zoöids. Surface flat or undulated, covered with tubercles. Astrorhizæ not developed.

As the type of this genus we may take a singular Stromatoporoid (*R. macrocystis*, n. sp.) from the Wenlock Limestone of Gotland, of which, through the kindness of my friend Dr. George J. Hinde, I have been enabled to examine specimens. A nearly allied type is the *R.* (*Stromatopora*) *dentata*, Rosen, of the Silurian Rocks of Oesel; and the form which the same author has described under the name of *Stromatopora Ungerni* ("Die Natur der Stromatoporen," Taf. ix, figs. 5 and 6), should also be placed here. I am, further, acquainted with two or three undescribed forms of the genus. One of these is a large form from the Ordovician deposits of Ayrshire, which Mrs. Robert Gray has been good enough to submit to me from her unrivalled collection of the fossils of the Palæozoic Rocks of Ayrshire, and which, though in bad preservation, seems to be properly referable to this genus.

The genus *Rosenella* is nearly related to *Labechia*, E. and H., on the one hand, while it has certain striking relationships with *Clathrodictyon*, Nich. and Mur., on the other hand. With his usual acumen, Prof. Ferd. Roemer had recognised the relationships of *Stromatopora dentata,* Rosen, with *Labechia,* to which genus he had, indeed, transferred the species ('Leth. Pal.,' p. 543). As based upon the type-form, *R. macrocystis,* n. sp., the genus *Rosenella* differs, however, from

Labechia in the very rudimentary condition of the radial pillars, and also in the correspondingly increased development of the vesicular laminæ. In *Labechia* (Fig. 5), the cœnosteum consists of strong, "continuous" radial pillars, separated and united by curved vesicular plates which carry no tubercles. In *Rosenella*, on the other hand, the cœnosteum (Plate VII, fig. 12) consists wholly of curved vesicular plates, which are not traversed by continuous radial pillars, but have the whole of their upper surfaces covered with rudimentary pillars in the form of conical tubercles. Tangential sections (Plate VII, fig. 13) show sometimes the cut edges of the curved vesicular plates, sometimes the transversely divided tubercles which spring from these plates, and sometimes the porous tissue of the plates themselves. The type-species of the genus is remarkable for the large size of the elongated cells which form the cœnosteum, single vesicles being sometimes an inch or more in length; but in other species (*e.g. R. dentata*, Rosen) the vesicles are much smaller. There are certain forms of the genus which show a singular transition between this and *Clathrodictyon;* but I shall be able to speak more definitely on this point later on.

Genus DICTYOSTROMA, *Nich.*

('Palæontology of Ohio,' vol. ii, p. 254, pl. xxiv, fig. 6, 1875.)

This genus was founded by me for the reception of a singular Stromatoporoid (*Dictyostroma undulatum*) from the Niagara Limestone of North America. As I unfortunately prepared at the time no thin sections of this form, and now possess no examples of it, the genus cannot be regarded as being adequately defined or satisfactorily established. The merely macroscopic characters of *D. undulatum*, so far as they can be used as a guide, would seem to show that *Dictyostroma*, if on further investigation it should prove to be a valid genus, is closely allied to *Rosenella*. Possibly, if its minute structure were known, it might be found to embrace the types which I have here referred to *Rosenella*, but on this point nothing certain can be said at present.

The cœnosteum in *Dictyostroma* consists of very thick, undulating, concentrically-disposed calcareous laminæ, which are separated from one another by intervals of about their own width (about two thirds of a millimetre), and which give off from their upper surface strong, remote, pointed radial pillars, which appear to reach the under surface of the lamina next above that from which they spring, but do not become amalgamated with it. The broken edges of the laminæ, when seen in vertical fractures, exhibit minute rounded apertures, but the precise nature of these could only be determined by means of thin sections.

Genus BEATRICEA, *Billings.*

(' Geol. Survey of Canada, Report of Progress for 1856,' p. 343, 1857.)

Cœnosteum in the form of cylindrical or angulated stems, which are nearly straight, are unbranched, and may attain a great size. (Billings states that specimens are sometimes over ten feet in length and more than a foot in diameter.) In the centre of the cœnosteum, running along its whole length, is a large axial tube, crossed by strongly curved calcareous partitions, or tabulæ, the remainder of the skeleton being composed principally of lenticular calcareous vesicles, arranged in concentric layers round the axial canal (Plate VIII, figs. 2 and 3). Well-preserved specimens exhibit radial pillars, resembling those of the Stromatoporoids generally, which intersect the vesicular tissue of the skeleton, and are directed outwards in a radiating manner from the axial tube towards the surface. No zoöidal tubes are certainly known to exist. The surface is ridged, or covered with elevated and usually elongated projections or mamelons (Plate VIII, fig. 1). The surface may be apparently imperforate, or may show minute rounded apertures of different sizes (Plate VIII, fig, 8). There is no external calcareous membrane, such as would correspond with the "epitheca" of a Rugose Coral.

The fossils for which Mr. Billings proposed the name of *Beatricea* are of a most anomalous character, and have been assigned to very different positions in the animal kingdom by different observers. Most generally they have been regarded as aberrant types of the Rugose Corals, and have been placed in the neighbourhood of the genus *Cystiphyllum*, a view which is borne out by the broad features of their skeletal structure, but which is rendered untenable by a study of the microscopic characters of the same. They have been referred by Professor Winchell to the Stromatoporoids; but I have not succeeded in finding any published account of this view, or of the grounds upon which it was based. The most recent opinion upon the subject of the affinities of *Beatricea* is that of Professor Hyatt, who formerly referred the genus to the *Cephalopoda,* but who has been led to the conclusion that it is properly to be placed among the *Foraminifera* (' Amer. Assoc. for the Adv. of Sci.,' 1884).

My own studies upon *Beatricea* have been based in part upon specimens from the Cincinnati Group of Kentucky, and partly upon a number of very interesting examples which my friend Mr. Whiteaves, the accomplished palæontologist to the Geological Survey of Canada, was good enough to send me. These latter were obtained from the Hudson-River formation of Anticosti and of Rabbit Island, Lake Huron. The two species originally described by Mr. Billings, viz. *B. nodulosa* and *B. undulata,* were both represented in the material which I have examined.

One of the great difficulties connected with the study of *Beatricea* arises from its apparently uniformly poor state of preservation. The skeletal tissue seems to have been very delicate and apparently very readily dissolved; hence the central portions of the cœnosteum are very commonly more or less largely replaced by calcite, while larger or smaller tracts throughout the skeleton are either similarly replaced, or are completely broken up. Moreover, even where the actual structure of the skeleton has been retained, it seems to have undergone some secondary change which has rendered its interpretation exceedingly difficult, certain parts of all the sections which I have prepared always showing a cloudy and granular aspect by which the minute details are hopelessly obscured.

The two conspicuous features in the skeleton of *Beatricea*, as displayed by transverse or longitudinal sections of the cylindical cœnosteum (Pl. VIII, figs. 2 and 3), are the axial tube and the peripheral vesicular tissue. The axial tube is a longitudinal canal, generally 5—6 mm. in diameter, running the entire length of the cylindrical cœnosteum. It has no definite walls, but is formed by the superposition of a series of deeply convex vesicles of large size, the convexities of which are all turned in one direction (Pl. VIII, fig. 3). Whether the convexities of these curved tabulæ point to the distal or to the proximal end of the cœnosteum I am unable to say, but I incline to think that they point to the former.

The remainder of the skeleton is formed by a thick sheath of vesicular tissue, formed of lenticular calcareous cells, arranged in successive concentric zones round the axial canal, and having a general long diameter of from 1 to 3 mm., their convexities being uniformly turned towards the exterior of the cylinder. The general character of the vesicles, superficially at any rate, is very similar to that of the cellular tissue of *Cystiphyllum;* and, if we take the axial canal as representing a central tabulate area, there would be considerable ground for regarding *Beatricea* as an ally of the Cystiphylloid Corals.

The structure of the vesicles is, however, not so simple as might at first sight appear. In all thin sections, in whatever direction they may be taken, the interior of the vesicles is more or less extensively occupied by ill-defined granular calcareous matter, which, beyond doubt, belongs to the skeleton of the fossil. Sometimes the entire cavity of the vesicle is filled with this granular tissue, but more often the vesicle is only lined with it, the lining being often confined to the convex margin of the vesicle, the rest of the space being filled up with calcite. That this granular tissue is properly part of the cœnosteum, and not a mere product of mineralisation, is shown by two facts. In the first place, in certain specimens, towards the exterior of the cylinder, the walls of the vesicles disappear to a larger or smaller extent, and then the granular matter which lined them forms a series of concentric laminæ, resembling the "laminæ" of an ordinary Stromatoporoid. In the second place, most specimens have this granular material in the

interior of the vesicles so arranged as to leave a larger or smaller number of clear lines which radiate from the convex outer margins of the vesicles towards their shorter inner sides (Plate VIII, fig. 5). This is one of the points concerning which one is unfortunately left in the dark owing to the imperfect preservation of the specimens; for out of a large series of sections, taken tangentially, transversely, and longitudinally, I fail to find one in which this structure is so clearly shown as to allow of a definite interpretation of its nature, though all show it more or less. All that I can say is that it reminds one, to some extent, of the arrangement of the rudimentary radial pillars on the surface of the vesicles of *Rosenella macrocystis* (Plate VII, fig. 12).[1]

The most characteristic structures of the Stromatoporoids, however, are the "radial pillars," and I am now able to show that apparently similar structures exist in *Beatricea* in a well-marked form. Here, again, we have the disappointing fact that these structures, owing to the state of preservation of the specimens, are not uniformly to be recognised. Even in specimens in which they are well shown they are only to be found in portions of the cœnosteum, having apparently disappeared elsewhere; or if they are present, the ordinary vesicular tissue is apt to be wanting. In certain specimens, however, the vesicles and the radial pillars are preserved in the same section (Plate VIII, fig. 4), in which case the pillars are seen as strong, apparently hollow rods, which are directed outwards in a radiating manner from the axial canal towards the circumference, and which are united to one another by the vesicular tissue. In this case, therefore, the structure is essentially the same as is observed in the genus *Labechia*, E. and H.

In another, very large specimen, for which I am indebted to Mr. Whiteaves, the inner layers of vesicular tissue, in the vicinity of the axial canal, show no traces of the radial pillars; but these latter structures are very well preserved in the peripheral zone of the cœnosteum. Transverse or longitudinal sections of this region of the skeleton show a general structure quite similar to what we might expect in any Stromatoporoid. Such sections (Plate VIII, fig. 6) show a series of strong radial pillars radiating from the central portion of the skeleton towards the circumference, and united by well-marked concentric "laminæ," which undulate in conformity with the surface-elevations. Both the pillars and the laminæ are composed of granular matter, showing well-marked dark points. The ordinary vesicles are present here and there among the pillars, and run parallel to the laminæ; but they are mostly wanting, in which case the concentric laminæ seem to be formed out of the granular lining which is seen in all the vesicles. Tangential sections, taken close to the circumference (Plate VIII, fig. 7), also show

[1] In one section of *Beatricea nodulosa*, Bill., I have noticed perpendicular calcareous septa crossing the vesicles, but whether or not this has anything to do with the appearances described above I am unable to say.

appearances very similar to that of corresponding sections in an ordinary Stromatoporoid, such as any species of *Clathrodictyon*. We see, namely, a number of close-set, rounded or oval, granular masses, which represent the ends of the transversely-divided radial pillars. These are also highly granular, and they are sometimes unquestionably hollow, though at other times they appear to be solid. The section further shows curved tracts of dark granular matter, formed by the close apposition of the cut ends of the pillars, and representing the points where the plane of the section corresponds with the plane of one of the undulating concentric laminæ.

Lastly, the surface of this remarkable specimen (Plate VIII, fig. 8) exhibits innumerable small rounded apertures, of which some are larger than the others, and are arranged in irregular longitudinal lines, which have seemingly a tendency to assume a spiral direction. The larger openings are, almost certainly, the apertures of the hollow radial pillars, and possibly all are of this nature. I cannot be sure, however, that these openings are not the result of the removal of the outermost layer of the skeleton. No traces of similar openings can be detected on the surface of most specimens of the same species (*B. nodulosa*, Bill.), though their absence may only be due to their bad state of preservation.

It need only be added that though the other species of *Beatricea* described by Billings, viz. *B. undulata*, is distinguished from *B. nodulosa* by its external form, its general structure is precisely the same. I have not, however, succeeded in recognising definite radial pillars in *B. undulata*, though I do not doubt they would be found were a sufficiently large series of specimens examined by means of thin sections.

Upon the whole, the balance of evidence seems to me to be in favour of regarding the genus *Beatricea* as an abnormal type of the Stromatoporoids. I do not recognise any Foraminiferal affinities in it; and there are various points in its structure, as above described, which seem quite incompatible with its being a Cystiphylloid Coral. On the other hand, it presents many of the features of the Stromatoporoids. This is especially the case as regards its possession of "radial pillars," and when these structures are combined with vesicles, the appearances presented are hardly distinguishable from what is observable in sections of *Labechia*. Moreover, one of its most abnormal features, namely, the possession of an axial tabulate tube, finds a parallel in the genera *Idiostroma*, *Stachyodes*, and *Amphipora*. I was, indeed, at first disposed to place it in the family *Idiostromidæ*, on the ground of this peculiarity alone; but the general structure of its tissues is such that, if it be regarded as one of the Stromatoporoids, it would seem to find its most natural place in the neighbourhood of the genera *Labechia* and *Rosenella*. The genus *Beatricea*, in fact, occupies with regard to *Labechia* the same place that the genus *Idiostroma* does to *Stromatopora*. It may, however, be a question, whether, in view

of its numerous peculiarities, it would not be expedient to regard *Beatricea* as the type of a special family.

Fam. 3. Stromatoporidæ, *Nich.*

Cœnosteum massive, laminar, dendroid, or encrusting, often with a basal epitheca. Radial pillars usually more or less extensively combined with their horizontal connecting-processes, so as to give rise to a continuously reticulated skeleton. The skeleton-fibre is thick, and is minutely porous or tubulated. Definite zoöidal tubes, crossed by well-developed "tabulæ" are present; but the cœnosteum is not traversed by a tabulate axial tube.

I include in this family the two principal genera *Stromatopora*, Goldf., as here emended, and *Stromatoporella*, gen. nov. The forms which have been referred by Bargatzky to *Parallelopora* and by myself to *Syringostroma* also belong to the family, but it is questionable if these names can be regarded as of more than subgeneric value. Moreover, most of the forms which have been referred to the genera *Caunopora*, Phill., and *Diapora*, Barg., are essentially referable to this family, but as the true nature of these so-called genera is a matter of great intricacy, I shall discuss it separately later on.

In the typical members of this family, namely in the species of *Stromatopora* itself, the skeleton is a completely reticulated one, and the radial pillars can hardly be said, as a rule, to have any existence as distinct structural elements. In the vermiculate structure of the skeleton, and in the presence of definite tabulate zoöidal tubes, the typical *Stromatoporæ* make a decided approach to the recent genus *Millepora*, Lam. In fact, the most striking points in which they differ from the latter are that they do not appear usually to have possessed more than a single series of zoöidal tubes, while the general skeleton-fibre has a peculiar and characteristic microscopic structure (Plate I, figs. 3—7, and Plate XI, figs. 1—4). There are, however, good reasons, apart from mere general likenesses in form and mode of growth, for not removing the *Stromatoporidæ* far from the *Actinostromidæ*. Thus, though there are wide differences between a typical *Stromatopora* and a typical *Actinostroma*, nevertheless the groups which these respectively represent are closely linked together by various transitional forms. In the vesicular cœnosteum of *Clathrodictyon* we have an approximation to the reticulate skeleton of the *Stromatoporidæ*; while in the genus *Stromatoporella* the radial pillars are so far distinct that vertical sections have a general resemblance to those of *Actinostroma* itself. Again, in *Stromatopora Beuthii*, Barg. (Plate V, figs. 12 and 13), the radial pillars, which are so characteristic of the *Actinostromidæ*, are more or less obviously

persistent in the interior of the reticulate skeleton-fibre. Many Stromatoporoids, moreover, possess exceedingly well-developed astrorhizal canals, the structure of which is entirely similar to that of the same structures in the Actinostromids.

Genus Stromatopora, *Goldf.* (emend.)

('Petrefacta Germaniæ,' Bd. i, p. 21, 1826.)

Cœnosteum usually massive or laminar, and generally furnished with an epitheca. The skeleton is completely reticulate, the radial pillars and their connecting-processes being so far fused together as to give rise to a trabecular or vermiculate tissue, traversed by irregular zoöidal tubes. Concentric laminæ are usually very imperfectly developed. The growth is very commonly by "latilaminæ," the radial pillars being continued from the top to the bottom of each latilamina; but it is rare for the pillars to have any distinct existence as separate structures. The zoöidal tubes appear to be in general of one kind only, and they are traversed by a larger or smaller number of transverse partitions or "tabulæ." Astrorhizæ are usually largely developed.

As previously explained, the genus *Stromatopora*, Goldf., has hitherto been generally taken as including the forms which have been here placed in the genus *Actinostroma*. I have, however, examined the original type-specimen of *S. concentrica*, Goldf. ('Petref. Germ.,' Taf. VI, fig. 5), of which Prof. Schlüter was so good as to have thin sections prepared. I have also made a minute examination of a number of examples which I collected in the Eifel myself, and which in all respects agreed precisely with the type-specimen of *S. concentrica*, the type-species of the genus *Stromatopora*, Goldf. The result of this has been to render it certain that the genus *Stromatopora*, Goldf., comprises forms entirely distinct from those which have usually been placed under this head. The genus is, in fact, the representative of a large and very natural series of Stromatoporoids which abound in the Silurian (Upper-Silurian) and Devonian formations. One well-marked example of this genus was described by Dr. Murie and myself from the Niagara Limestone of North America under the name of *Pachystroma antiquum* ('Journ. Linn. Soc.,' vol. xiv, p. 223, 1878), and we made this the type of the new genus *Pachystroma*. This genus must, however, be now regarded as a synonym of *Stromatopora*, Goldf. Other types of the genus *Stromatopora* have been described by different authors as belonging to the so-called "*Caunopora*" of Phillips; but I shall subsequently show that whatever conclusion we may form as to the nature of "*Caunopora*," it cannot be regarded as a *genus* of Stromatoporoids.

The general texture of the skeleton in the genus *Stromatopora*, Goldf., is often

extremely dense, and the formation of the cœnosteum out of successive "latilaminæ," each of which marks a periodic cessation of growth, is also often a conspicuous feature. Vertical sections (Plate V, figs. 10, 13, 15, 17, and Plate XI, fig. 18) show indistinct parallel radial pillars, more or less wavy and united at intervals by irregular horizontal processes, or by partial confluence with one another. Between the irregular pillars are the vertical but similarly irregular zoöidal tubes, usually crossed by very well-developed "tabulæ."

Tangential sections (Plate V, figs. 11, 13, 14, 16, and Plate XI, fig. 16) exhibit a vermiculate and continuously reticulate framework, traversed by the irregular apertures of the zoöidal tubes, and thus, but for the absence of "gastropores," in many respects resembling corresponding sections of *Millepora*. Such sections also, as a rule, exhibit extremely well-developed stellate cœnosarcal canals or "astrorhizæ." As a rule, tangential sections exhibit no traces of the cut ends of the radial pillars, as distinct structures, but such may occasionally be detected. Thus, in well-preserved examples of *S. Beuthii*, Barg., from the Devonian Rocks of Germany and Britain, the transversely divided ends of the radial pillars can usually be recognised in tangential sections as opaque round masses immersed in the general reticulate tissue of the skeleton (Plate V, fig. 12). The same phenomenon is seen, but less clearly, in some other types.

The genus *Stromatopora*, Goldf., attains its maximum in the Devonian Rocks, but several Silurian species are known. One of the most abundant of the Silurian types is *Stromatopora typica*, Rosen, which is apparently not separable from the *S. astroites* of the same author, and which occurs in vast abundance in the Wenlock Limestone of Britain and in the Upper-Oesel beds of Esthonia. An allied type is *S. Carteri*, n. sp., from the Wenlock Limestone of Britain; and a third interesting form is the *Stromatopora discoidea*, Lonsd. sp. (= *S. elegans*, Rosen), which is found in the Upper-Silurian series of Britain, Gotland, and Esthonia. In the Devonian Rocks of Britain and Germany the type-species, *S. concentrica*, Goldf., is of decidedly rare occurrence; but *S. Hüpschii*, Barg., sp., *S. Beuthii*, Barg., and *S. bücheliensis*, Barg., sp., are all abundant and characteristic types, while other less completely known forms are also present.

Genus STROMATOPORELLA, *gen. nov.*

Cœnosteum usually expanded, mostly laminar, and furnished with a basal epitheca; sometimes thin and encrusting. Skeleton imperfectly reticulate, not growing in "latilaminæ," or exhibiting such a structure in but an imperfect form. Both the concentric laminæ and the radial pillars are comparatively well developed, and are only partially fused to form a reticulate framework. Zoöidal tubes are

present, but they are irregular, short, comparatively few in number, and in general but sparingly furnished with tabulæ. Astrorhizæ are, as a rule, largely developed, and are commonly intersected by internal partitions or "astrorhizal tabulæ;" while they are often superposed in successive interlaminar spaces, in which case the members of each series are connected by one or more vertical canals. Skeleton-fibre minutely porous, or traversed by irregular microscopic tubuli (Plate I, figs. 4 and 5; Plate XI, figs. 1—4).

It is difficult to rigidly define the present genus, as in many of its characters it occupies an intermediate position between *Stromatopora*, Goldf., and *Actinostroma*, Nich. It agrees with *Stromatopora* in the minutely porous structure of the skeleton-fibre, in the fact that the skeletal elements are in part fused with one another, so as to form an imperfectly continuous framework, and in the possession of distinct tabulate zoöidal tubes. On the other hand, owing to the incomplete fusion of the horizontal and radial elements of the skeleton, there is a considerable resemblance between *Stromatoporella* and *Actinostroma*. Thus, in vertical sections (Plate VII, figs. 4 and 6) the concentric laminæ and the radial pillars are usually perfectly recognisable, and are often quite distinct. In tangential sections also (Plate VII, figs. 3 and 5), though we have in part the vermiculate network so characteristic of the Stromatoporids, we likewise observe the detached ends of the transversely-divided pillars, which form so conspicuous a feature in tangential sections of *Actinostroma* or *Clathrodictyon*.

Of the peculiar characters of the genus *Stromatoporella*, one of the most important is the nature of the zoöidal tubes. In the type-species of the genus (*S. granulata*, Nich.), the zoöidal tubes have the form of short irregular tubes, which often only lead from one interlaminar space to the next, or, at most, to the next space but one, and which are crossed by but few tabulæ (Plate II, fig. 10, and Plate VII, fig. 6). In tangential sections (Plate I, fig. 15, and Plate VII, fig. 5) are seen numerous complete or incomplete rings, which represent these irregular zoöidal tubes transversely divided. Moreover, the surface (Plate I, fig. 14, and Plate IV, fig. 6) exhibits numerous large-sized tubercles, the centres of which are perforated by round apertures, which we may suppose to have served for the emission of zoöids. In *Stromatoporella* (*Diapora*) *laminata*, Barg., the zoöidal tubes are more numerous, are longer, and are more richly furnished with tabulæ, but the general structure is the same as in *S. granulata*, Nich. In this species also the surface, in well-preserved examples, exhibits numerous perforated tubercles (Plate X, fig. 4) which probably gave exit to the zoöids of the colony.

Astrorhizal canals are also very extensively developed in most of the *Stromatoporellæ*, and are sometimes of very large size (Plate IV, fig. 2). In this genus, the astrorhizal canals are very commonly intersected by irregular partitions, or "astrorhizal tabulæ" (Fig. 7, and Plate VII, fig. 3). In some cases, these parti-

tions are simply transverse, but in other cases they may be vesicular, or almost funnel-shaped. Very probably connected with these astrorhizal tabulæ are the curved, oblique, or irregular partitions which are seen crossing the interlaminar spaces in almost all the species of *Stromatoporella* (Plate VII, fig. 4).

Many of the types which exhibit the above general characters are encrusting, but they are by no means always so, and *S. granulata*, Nich., the type-species, appears to be always a free laminar expansion, with a basal epitheca. Not only are they very variable as to their mode of growth and general form, but they also vary much as to certain details in their actual structure.

Much more labour, therefore, will be required before it will be possible to speak positively as to the number and limits of the species which belong here. All the forms of this genus which have come under my observation belong to the Devonian formation. The type-species is *S. granulata*, Nich. ('Ann. and Mag. Nat. Hist.,' 1873), which is abundant in the Hamilton and Corniferous formations of Western Canada. Closely allied to this is a beautiful species which occurs commonly in the Devonian Limestones of the Eifel, and which I shall provisionally name *S. eifeliensis.* The microscopic structure of these two forms (Plate VII, figs. 3 and 4, and figs. 5 and 6) is very much the same; but *S. eifeliensis* possesses remarkably well-developed astrorhizæ, and has certain other structural peculiarities which will probably entitle it to specific distinction. In various features, the form described by Mr. Carter as *Stromatopora dartingtonensis* makes a close approach to the above-mentioned forms; but it seems to possess some special characters of its own, and will require further investigation. Related to the preceding also is the singular Stromatoporoid of the Devonian Limestones of the Paffrath district, which Bargatzky described as *Diapora laminata*, and on which he founded the genus *Diapora*. This being the case, it might have been proper, in accordance with the strict laws of priority, to retain the name of *Diapora* for the present genus. Bargatzky, however, made the essential character of his genus *Diapora* to consist in the possession of thick-walled "Caunopora" tubes, the genus being only separated from the so-called "*Caunopora*" of Phillips by the character of the tissue surrounding these tubes. As, however, I am able to show that the said thick-walled tubes—whatever their nature may be—are merely of occasional occurrence, and that they only constitute a particular phase in the history of certain kinds of Stromatoporoids, it seems clear that it would be highly unadvisable to retain the names *Caunopora*, Phill., and *Diapora*, Barg., as the titles of *generic* divisions. It could, in fact, only lead to confusion to retain these names for forms in which the characteristic thick-walled tubes, upon the existence of which these genera were established, are commonly wholly wanting. For this reason, therefore, I have thought it best to give the new name of *Stromatoporella* to the group of forms at present in question.

In addition to the forms above alluded to there are several other imperfectly known Stromatoporoids which probably belong to this genus. It is tolerably certain, namely, that some of the forms included by Goldfuss under the name of *Stromatopora polymorpha* (*e. g. S. curiosa*, Barg.) are really referable to *Stromatoporella*. The *Stromatopora nulliporoides*, Nich., of the Devonian of North America, and the allied, or identical, *Cœnostroma incrustans*, Hall and Whitf. (Plate III, fig. 6), from the same formation, are likewise probably referable here.

Genus Parallelopora, *Bargatzky*.

('Die Stromatoporen des rheinischen Devons,' p. 63, 1881.)

The general structure of the skeleton in the forms which Bargatzky placed under *Parallelopora* resembles that of the typical *Stromatoporæ*, the radial and horizontal elements of the skeleton being so amalgamated as to give rise to a continuously reticulated framework, traversed by vertical tabulate zoöidal tubes. The coarse, reticulated skeleton-fibre is traversed by irregular vertical tubuli, or by minute dark-coloured vertical rods, which are united at intervals by horizontal bars. Astrorhizæ are present.

It seems doubtful if *Parallelopora*, Barg., can be regarded as having the rank of a genus. The general structure of such forms as I have seen (including Bargatzky's original specimens) would appear to be very much the same as that of *Stromatopora*, Goldf., or of *Idiostroma*, Winch., some of the described species being more like the former genus, and others more like the latter. The peculiarities in the structure of the forms in question are, in fact, chiefly concerned with the existence in the skeleton-fibre of minute vertical tubules, in many respects similar to the tubuli seen in *Stachyodes*, Barg. In one form, viz. *P. Goldfussi*, Barg., of which I have examined the original specimen, the skeleton-fibre is coarsely tubulated (Plate XI, fig. 9); but the general structure is not otherwise peculiar. I am disposed to think this species to be really identical with *Idiostroma?* (*Stromatopora*) *capitatum*, Goldf.

More remarkable appearances are presented by *P. ostiolata*, Barg., from the original of which, through the kindness of Prof. Schlüter, I have also prepared thin sections. In tangential sections of this type, as previously mentioned, the skeleton is seen to be densely reticulated, and to be traversed by numerous rounded zoöidal tubes (Plate II, fig. 6). The skeleton-fibre is very thick and very transparent, so that it is in places difficult to distinguish it from the surrounding calcitic matrix. It is, however, distinctly marked out by a vast number of rounded

or oval black dots, which are scattered through the thickness of the fibre, but are most abundant round the margins of the zoöidal apertures. These dots have every appearance of being solid, the use of a quarter-inch objective showing them to be granular in texture and to have no distinct lumen. In *vertical* sections (Plate II, fig. 7) the thick radial pillars are seen to separate vertical zoöidal tubes, which are crossed by well-developed transverse partitions or tabulæ. The radial pillars are further traversed by minute dark-coloured vertical rods, which run parallel to one another and to the zoöidal tubes, and which are connected at short intervals by similar transverse rods, giving rise to a sort of ladder-like tissue. These rod-like bodies appear to be solid, and the dark dots in the tangential section are their transversely divided ends.

Dr. Bargatzky (*loc. cit.*) considers these rod-like bodies to be the walls of interstitial tubes occupying all the spaces between the larger tubes, and he regards the transverse rods which connect these as being the "tabulæ" of these interstitial tubes. On this view the structure would be very much the same as that of such Corals as *Heliolites* or *Callopora*. Tangential sections, however, show conclusively that the dark vertical lines which run in the spaces between the ordinary zoöidal tubes, are not the *walls of tubes*, but that they are *rods*, and that they are contained *in the interior of a reticulated skeleton-fibre.* I am therefore unable to accept Dr. Bargatzky's views upon this point, though it is not possible to give an absolutely satisfactory explanation of the nature of these curious structures. Two conjectures might, in fact, be hazarded as to their nature. They have a general resemblance, especially in vertical sections, to the radial pillars and their horizontal connecting-processes as seen in the typical *Actinostromæ*. We might therefore regard these rods as being the radial pillars and "arms" of an *Actinostroma* persisting in the general reticulate skeleton-fibre, a phenomenon which can be observed to a certain extent in such forms as *Stromatopora Beuthii*, Barg. On the other hand, a much more probable hypothesis—and one supported by the observed phenomena in other cases—is that these rod-like bodies are really of the nature of minute canals in the skeleton-fibre, which have been injected with some dark-coloured and opaque material. This conjecture is not absolutely incompatible with the former hypothesis, since such canals might represent the axial tubes of a system of radial pillars and their horizontal connecting-processes. On this view the structure of the skeleton in *Parallelopora ostiolata*, Barg., would become comparable with that of *Hermatostroma.* Or we might suppose the canal-system to be of the same type as the remarkable tubulation of the skeleton-fibre in the genus *Stachyodes*, Barg., in which the tubuli are sometimes filled with transparent calcite, or at other times are occupied by opaque oxide of iron. It seems, however, hardly possible to arrive at final conclusions as to the structure of *Parallelopora* until a more abundant material shall have been collected and examined.

Genus SYRINGOSTROMA, *Nich.*

('Palæontology of Ohio,' vol. ii, p. 251, 1875.)

Cœnosteum massive, formed of successive "latilaminæ." Skeleton-fibre minutely porous. The skeletal tissue is, on the whole, of the reticulated type characteristic of the *Stromatoporidæ*, but the radial pillars are distinctly recognisable and some of them may be of large size. Astrorhizæ are largely developed.

I originally founded this genus for a singular Stromatoporoid (*S. densum*) from the Devonian Rocks of Ohio. My material is unfortunately very limited, but I have recently succeeded in preparing good thin sections, and can therefore speak more confidently as to the real structure of this type. In the minutely porous character of the skeleton-fibre, as also in the essentially reticulate structure of the skeletal tissue (Plate XI, fig. 13), *S. densum* quite resembles the species of *Stromatopora*, Goldf. It has, however, the peculiarity that the cœnosteum is traversed at intervals by large-sized radial pillars which are recognisable in both tangential and vertical sections (Plate XI, figs. 13 and 14). I should not have been disposed to regard this feature as of generic value, except that I have recently had the opportunity, through the kindness of Professor J. W. Spencer, of examining an apparently related form which certainly seems worthy of generic distinction. The form in question was described by Professor Spencer from the Upper Silurian formation of New Brunswick ('Bulletin of the Mus. of the Univ. of the State of Missouri,' p. 49, 1884), under the name of *Cœnostroma ristigouchense*. Tangential and vertical sections of this beautiful type (Plate XI, figs. 11 and 12) show a curious combination of the characters of *Stromatopora*, Goldf., and *Actinostroma*, Nich. Thus, the skeleton-fibre has to a marked extent the minutely porous structure which is so characteristic of *Stromatopora*, properly so called; while the radial pillars and their connecting-processes are as distinctly and clearly developed as in the type-forms of *Actinostroma*. The radial pillars, in fact, are exceedingly large, and give off whorls of delicate "arms" or connecting-processes, which are emitted at corresponding levels in a radiating manner, and which circumscribe rounded pores representing the zoöidal tubes. The astrorhizal canals are largely developed, and we therefore see in vertical sections (Plate XI, fig. 12), as in similar sections of *S. densum*, the large rounded apertures which represent the cut ends of these tubes, and upon which the genus *Syringostroma* was originally based. This latter character is, of course, one of no generic importance, as, indeed, present in all Stromatoporoids with large astrorhizal canals. There can, however, be little hesitation in regarding this type as really distinct from both *Stromatopora* and

Actinostroma; and it appears to have various structural relationships with the form which I described as *Syringostroma densum.* Pending fuller investigation, I shall therefore place it under the head of *Syringostroma.* The validity of this, however, either as a genus or sub-genus, will, of course, depend upon further and more exhaustive researches into the minute structure of the type-species, *S. densum*, Nich.

Fam. 4. Idiostromidæ, *Nich.*

The cœnosteum in this family is dimorphic, and the general skeletal tissue is in the main reticulated, but the radial pillars and concentric laminæ are usually developed as clearly distinct structures. The skeleton-fibre may be porous, or tubulated, or apparently compact (*Amphipora*). Definite zoöidal tubes, often extensively tabulate, are generally present. There are also present larger tubes, likewise tabulate, and sometimes furnished with distinct walls. These may be distributed irregularly through the cœnosteum; but they more usually form a single or multiple "axial tube," which gives off lateral tabulate branches. The typical form of the cœnosteum is that of a cylinder, sometimes simple, sometimes branched, sometimes fasciculate, but in other cases the skeleton may be massive or spheroidal. Astrorhizæ do not appear to be developed.

I propose to provisionally group together under the above head the four genera, *Idiostroma*, Winch., *Hermatostroma*, Nich., *Stachyodes*, Barg., and *Amphipora*, Schulz. It must be admitted that this arrangement is in important points not a natural one, and it is very probable that further researches may render its modification necessary. If we were to take the typical cylindrical or dendroid examples of *Idiostroma*, *Stachyodes*, and *Amphipora*, we should have a compact group of forms, distinguished by the shape of the colony, and by the possession of a main axial tube furnished with tabulæ, and connected with smaller tabulate offshoots. Both *Idiostroma* and *Stachyodes*, however, occur in massive or sub-massive forms, and in these there is no principal axial tabulate tube, but there are a number of such tubes irregularly distributed through the colony. This, in fact, is the only character of importance which would separate the massive examples of the former of these two genera from *Stromatopora*, Goldf. Then, again, the relationship between the massive forms of *Idiostroma* and the type which I have named *Hermatostroma*, is too close to allow of their separation to any distance from one another; though in the latter the characteristic large tabulate tubes of *Idiostroma* are either apparently wanting or are present only in a modified form. The type which Bargatzky named *Stachyodes* is in its general features very similar to the cylindrical forms of

Idiostroma, but can be readily distinguished from all the other members of this group by the peculiar minute tubulation of the skeleton-fibre. Lastly, *Amphipora*, Schulz, in the complete reticulation of its skeletal tissue, and in the apparently compact character of its skeleton-fibre, stands quite alone; though it agrees with the cylindrical forms of *Idiostroma* and *Stachyodes* in the shape of the cœnosteum, and in the very striking character that it possesses a principal axial tabulate tube. I should, however, be inclined to think that *Amphipora* might perhaps be regarded as the type of a separate group.

Genus IDIOSTROMA, *Winchell.*

('Proc. Amer. Assoc. Adv. of Science,' p. 99, 1867.)

The cœnosteum is typically cylindrical, sometimes fasciculate, sometimes massive or sub-massive. The general skeletal tissue is reticulated, but the radial pillars and concentric laminæ remain largely distinct from one another. The skeleton-fibre is coarsely porous. Definite zoöidal tubes, furnished with numerous tabulæ, and opening on the surface by rounded apertures, are present. In addition to the ordinary zoöidal tubes there are present larger tabulate tubes. In typical examples of the genus each cylinder of the skeleton has a single tabulate axial tube, which gives off secondary lateral tubes, also intersected by tabulæ. In the massive and sub-massive examples the large tubes are irregularly distributed through the mass. These tubes may be only bounded by the general tissue of the skeleton, or they may be enclosed by definite walls, which may be thickened towards their mouths. In any case the tubes communicate more or less extensively with the interlaminar spaces. The surface shows prominent pointed tubercles, often arranged in vermiculate ridges, which may radiate from prominent conical "mamelons," so as to form imperfect astrorhizæ. The openings of the small zoöidal tubes are placed in the grooves separating these vermiculate ridges. The conical "mamelons" may or may not have large apertures at their summits.

The genus *Idiostroma* was founded by Winchell for the reception of two species (*I. cæspitosum* and *I. gordiaceum*) from the Devonian Rocks of North America. *I. cæspitosum* has subsequently been described and figured, presumably from American specimens, by Quenstedt, under the name of *Stromatopora cæspitosa* ('Die Schwämme,' pl. 142, fig. 14, 1878). My own knowledge of the genus is based upon a large series of specimens belonging to three different species, of which two are common to the Devonian Rocks of Germany and of Devonshire,

while the third seems, so far, not to have been detected in Britain. One of the forms in question I am disposed to regard as probably the *Stromatopora* (*Tragos*) *capitata* of Goldfuss, which, again, not improbably, may be identical with the *Parallelopora Goldfussi* of Bargatzky. The other two forms have the typical cylindrical or fasciculate cœnosteum of the genus, and I shall speak of them by the provisional names of *I. Roemeri* and *I. oculatum;* since the descriptions of Winchell and Quenstedt are not sufficient to allow of any comparison of these with the two described American species.

Taking *Idiostroma Roemeri* (Pl. IX, fig. 6), of the Rhenish Devonian, as a typical example of the genus, the cœnosteum has the form of a generally branched cylindrical stem, rooted basally to some foreign object, which it may partially encrust. The stems vary from one to three centimetres in diameter, and they are sometimes so far confluent as to give rise to a sub-massive skeleton, in which the component cylinders are, however, still clearly recognisable. Both transverse and longitudinal sections (Pl. IX, figs. 7 and 8) show that each stem is traversed by a main axial tube, which is intersected by numerous transverse, vesicular, or funnel-shaped "tabulæ." This axial tube gives off lateral branches, which are also tabulate, and which ascend towards the surface, giving off secondary branches in their course. Sometimes there is more than one longitudinal tube, in which case the central one is the largest, and the subordinate tubes run parallel with it at a little distance. Whether the lateral branches given off from the main tube open on the surface by definite apertures, or whether the latter has an opening at the end of the stem, is in this species difficult to decide positively. Some of my specimens do not show any openings, except the minute apertures of the ordinary zoöidal tubes; but others exhibit here and there much larger perforations, which can hardly be anything else than the apertures of the lateral branches of the axial tube. These large apertures are often placed upon prominent elevations or "mamelons." There is no reason, so far I can see, for doubting that the large tubes above mentioned must have had definite surface-apertures, though these may not be visible in all specimens.

The surface of *Idiostroma Roemeri* is highly characteristic, and is covered with vermiculate ridges, formed by the confluence of rows of pointed tubercles, and separated by deep winding grooves (Plate IX, fig. 9). Often these ridges radiate from the apices of conical "mamelons," and in the intervals between them are seen the circular openings of the ordinary zoöidal tubes. Thin sections show that the cœnosteum is built up of numerous concentrically-disposed layers, which grow as a series of deeply convex caps round the free end of the stem, where each layer is thicker than elsewhere. The skeletal tissue is in the main reticulate, but the confluence of the radial pillars and their horizontal connecting-processes is not nearly so complete as in the *Stromatoporidæ*. Hence, not only are the radial

pillars thoroughly recognisable as distinct structures, but the concentric laminæ are conspicuous in both transverse and longitudinal sections of the stem. Transverse sections of the stems also show very clearly, as also longitudinal ones do less perfectly, that the entire cœnosteum is traversed by innumerable distinct zoöidal tubes, which radiate outwards from the axis of the stems to open on the surface by distinct apertures, and which are crossed by numerous curved or straight tabulæ (Plate IX, fig. 8). Lastly, thin sections show that the skeleton-fibre has the minutely porous character which is such a marked feature in the case of the species of *Stromatopora*, Goldf.

A second still more remarkable species of *Idiostroma* occurs in the Devonian Rocks of Britain and Germany, which may be provisionally distinguished by the name of *I. oculatum.* I was under the impression that this would prove to be identical with the fossil described and figured by Kayser from the Devonian Rocks of the Eifel under the name of *Trachypora circulipora* ('Zeitschr. der deutschen Geol. Gesell.,' 1879, p. 304, Taf. v, figs 2—4), with which it agrees closely in aspect and general appearance. Professor Schlüter, however, having examined the original specimens of *Trachypora circulipora*, Kays., informs me that though the fossil so named may be in part of the nature of a Stromatoporoid, it is not the same as the singular dendroid *Idiostroma* here in question. I have therefore thought it best to distinguish the latter by the above-mentioned title.

The cœnosteum in *Idiostroma oculatum* (Fig. 14) consists of slender cylindrical stems, from three to five mm. in diameter, which branch and inosculate freely, so

Fig. 14.

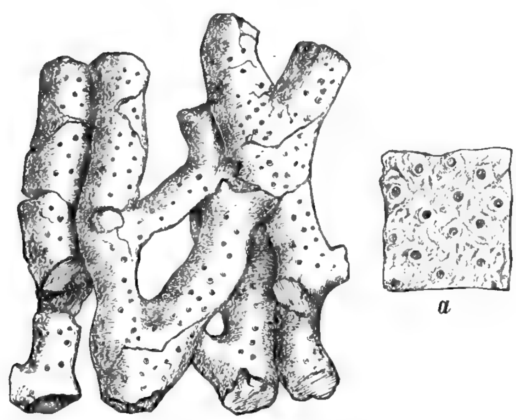


Fig. 14.—A fragment of the cœnosteum of *Idiostroma oculatum*, n. sp., of the natural size. Devonian, Büchel. *a*. A small portion of the surface enlarged

as to give rise to large fasciculate masses. The general structure of the skeleton is essentially the same as in the previously described *I. Roemeri.* Each cylindrical stem is traversed by a large axial canal, which is intersected by transverse, curved,

or vesicular tabulæ, and which gives off diverging lateral canals which are also tabulate. The general skeletal tissue is built up in concentric layers round the main axial tube (Fig. 15), the concentric laminæ and interlaminar spaces being thus very conspicuous. On the other hand, the radial pillars are proportionately much less developed than in *I. Roemeri*, while the small zoöidal tubes are tortuous and

FIG. 15.

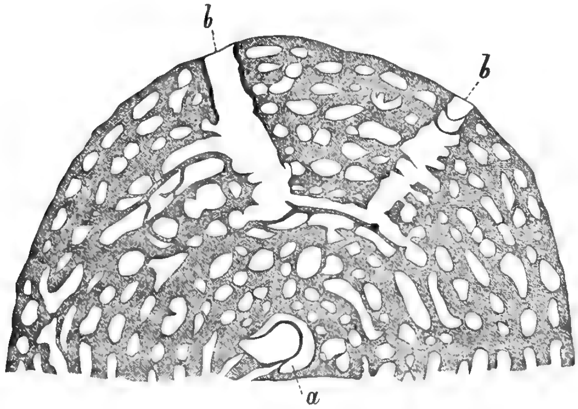


FIG. 15.—Transverse section of half of a stem of *Idiostroma oculatum*, n. sp., enlarged twelve times. *a.* The axial canal, transversely divided. *b b.* The large radial tubes, longitudinally divided, opening inferiorly into the interlaminar spaces, but acquiring thickened walls, and being intersected by tabulæ where they approach the surface.

irregular. Some specimens show no further character which would demand notice here, the surface being simply covered with small tubercles, often arranged in winding rows, and exhibiting here and there the minute openings of the ordinary zoöidal tubes. The majority of specimens, however, exhibit additional features of great interest and importance. In most specimens, namely, the surface everywhere exhibits a considerable number of round apertures, which are placed at tolerably regular intervals, are of much larger size than the openings of the ordinary zoöidal tubes, and are surrounded by thickened and elevated rims (Fig. 14, *a*). Longitudinal and transverse sections show that these apertures are the openings of large tubes, which are at first directed inwards, and then curve downwards as they approach the axis of the stems. These tubes (Fig. 15, *b b*) are intersected by curved or vesicular tabulæ, and they appear to be provided near their mouths with thickened *proper walls*. As they approach the axis of the stems, however, the thickened wall disappears, and they seem to be only bounded by the general tissue of the skeleton; while they finally *terminate by opening into the interlaminar spaces of the cœnosteum.* Whether or not they have have any direct connection with the axial tube which traverses each stem is a point very difficult to determine positively. The phenomena presented by longitudinal sections would, however, seem to show that such a connection certainly exists, in at any rate some instances.

I shall subsequently illustrate and describe the singular structures just alluded to more fully, but there are one or two general considerations which may be noticed here. It will be evident, namely, from the above description, that the tubes in question are in most respects identical with the tubes which occur in those Stromatoporoids which have been referred to the so-called genera "*Caunopora*," Phill., and "*Diapora*," Barg. In fact, the specimens would, in an ordinary way, be certainly regarded as belonging to a species of *Caunopora*. The tubes of *Idiostroma oculatum* resemble the embedded tubes of "*Caunopora*" and "*Diapora*" in opening on the surface by large prominent apertures, in having thickened walls, and in being intersected internally by tabulæ. They differ, however, from the tubes of "*Caunopora*" in the fact that the thickened wall seems to be confined to the outer portion of each tube, where it begins to approach the surface, and also in the important feature that the tubes to all appearance communicate freely internally with the interlaminar spaces of the skeleton—a communication which has not been proved to take place in the case of the tubes of "*Caunopora*," and which probably does not take place in the latter. Leaving the nature of "*Caunopora*" and "*Diapora*" for future consideration, it may be well to point out here the grounds for thinking that the embedded tubes of *Idiostroma oculatum* are certainly parts of the organism in which they are found; and there are two principal reasons for coming to this conclusion. In the first place, these tubes can hardly belong to any organism foreign to the Stromatoporoid in which they occur, seeing that they appear to be to a large extent bounded only by the proper skeletal tissue of the latter, while they seem clearly to open internally into the general cavities of the cœnosteum in which they are embedded. In the second place it is apparently inconceivable that the tubes of any Coral, such as *Aulopora* or *Syringopora*, could be embedded, parasitically or commensally, throughout the numerous slender and branching stems of *Idiostroma oculatum* in such a way that the mouths of the tubes, and the mouths only, should appear at the surface. If, indeed, we could remove the enveloping skeletal tissue of *Idiostroma oculatum*, and could inspect the embedded tubes alone, we should find a structure entirely unlike any known species of Auloporoid or Syringoporoid Corals. Moreover, the main axial tabulate tube of *I. oculatum* is, beyond all question, a part of the Stromatoporoid, and it is only close to the surface that the radial tubes exhibit any feature which would distinguish them from the axial tube, since it is only in this region that they appear to develop proper walls.

If we accept the conclusion that the radial tubes of *I. oculatum* belong to the organism in which they are found, it still remains to consider what these tubes *are*, and what functions we may suppose them to have discharged. As regards this point, it is to be observed, in the first place, that some specimens of *Idiostroma oculatum*, though possessing the axial tubes in the stems, show no traces of the

above-described radial tubes, while other specimens have every branch full of them. It is obvious, therefore, that the presence or absence of these radial tubes cannot be used as a generic, or even a specific character. It is an *individual* peculiarity with which we have to deal; and the tubes in question can therefore only be structures which are occasionally developed. The only structures, however, in an ordinary Hydroid colony which are present in some individuals of a species and not in others are the reproductive zoöids. Thus, if we accept the conclusion that the embedded radial tubes of *I. oculatum* belong to the organism in which they occur, we are apparently shut up to the further conclusion that they must have served for the lodgment of the reproductive zoöids. On this view, those specimens of *I. oculatum* which are destitute of these radial tubes represent the sterile colonies, while the more numerous "Caunoporoid" examples are the fertile individuals of the species. Upon the whole, therefore, while fully admitting the difficulty of anything like definite proof on the point, it seems to me that the most probable hypothesis as to the embedded tubes of *Idiostroma oculatum* is to regard them as connected with the function of reproduction, and as corresponding with the differently constructed "ampullæ" of the recent Stylasterids.

The only other species of *Idiostroma* with which I am personally acquainted is the form, previously alluded to, which I have dubiously identified with the *Tragos capitatum* of Goldfuss, and which I think is probably the *Parallelopora Goldfussi* of Bargatzky. This type occurs commonly in the Paffrath district, and is also not rare in the Devonian Limestones of Devonshire. It differs from *I. Roemeri* and *I. oculatum* in not being cylindrical or fasciculate in form, but in being massive or sub-massive, generally more or less spherical. Moreover, in place of a principal axial canal, giving off lateral tabulate branches, we find in this species numerous large tabulate tubes distributed irregularly through the cœnosteum, and quite distinct from the normal but also tabulate zoöidal tubes. In this species, we find, as I have formerly described, numerous lenticular or oval vesicles of comparatively large size, scattered through the general skeletal tissue (Fig. 8), and it may be conjectured that these are also of a reproductive nature, and correspond with the "ampullæ" of the Stylasterids. These vesicles are generally from one to three mm. in diameter, and are often crossed by internal partitions or tabulæ. They are often only bounded by the general skeletal tissue of the cœnosteum; but at other times they appear to have a thin proper wall of their own. Other specimens of this species exhibit somewhat similar cavities which are surrounded by greatly thickened walls; but I have not been able to make out whether these are a still further modification of the supposed "ampullæ" just spoken of, or whether they are not rather embedded adventitious structures.

Genus HERMATOSTROMA, *gen. nov.*

Cœnosteum massive, laminated, the surface of the concentric laminæ covered with low rounded elevations. The skeletal framework is incompletely reticulated, the radial pillars and their horizontal connecting-processes being largely distinct from one another. The radial pillars are "continuous," are very stout, and are traversed by very large axial canals. The horizontal "arms" or connecting-processes, out of which the concentric laminæ are composed, are also very stout, and the axial canals of the pillars are prolonged into these also. These processes give rise to well-marked and regularly disposed concentric laminæ, but they do not form by their anastomosis an *angular* meshwork, such as characterises the genus *Actinostroma.* On the contrary, they produce a network of rounded apertures (Fig. 1), which served for the emission of zoöids. Astrorhizæ are apparently wanting. Embedded in the tissues at tolerably regular intervals are short flexuous tubes of considerable size, bounded by thin proper walls, and crossed by occasional tabulæ. These tubes open on the surfaces of the concentric laminæ, often at the summits of the low prominences above spoken of, by large rounded apertures.

The above description is based upon a remarkable type which I collected from the Devonian Limestones of the Paffrath district, and which I have named *H. Schlüteri*, in honour of the distinguished palæontologist, Professor Schlüter, of Bonn, to whose kindness I have been greatly indebted in working out the Stromatoporoids of the Rhenish Devonian formation. An apparently allied form occurs in the Devonian Limestones of Devonshire, but I have not yet completely investigated its structure.

All the specimens of *Hermatostroma Schlüteri* which I have seen, have the canal-system of the radial pillars and concentric laminæ largely injected with some opaque material, apparently oxide of iron, the tubes in question being thus rendered extremely conspicuous in thin sections. Vertical sections (Fig. 16, B, and Plate III, fig. 2) show the large hollow pillars running continuously across the concentric laminæ for considerable distances, and forming with these a marked quadrangular meshwork. The canals of the radial pillars are filled with oxide of iron, and can thus be traced continuously into the concentric laminæ, being dilated at the crossing-nodes of these two sets of structures. Tangential sections (Fig. 1, and Plate III, fig. 1) vary in the appearances which they present, according as the line of section intersects the interlaminar spaces, or coincides with the concentric laminæ themselves. In the former case they show the round or oval ends of the transversely-divided radial pillars (Fig. 16, A), with their large axial tubes. In the latter case (Fig. 1, A), they show the rounded and variously-sized pores

formed by the inosculation of the horizontal connecting-processes given off by the radial pillars. These pores doubtless represent the sections of imperfect zoöidal tubes. In fact, vertical sections sometimes show such tubes, crossed by delicate transverse tabulæ, to be present; but they are always very irregularly and feebly developed. Both tangential and vertical sections show that the main canals of the radial pillars and concentric laminæ give off secondary tubuli, which inosculate to form a system of canaliculi traversing the substance of the skeleton-fibre. These secondary tubuli are best seen in sections traversing the concentric laminæ (Fig. 1, A).

FIG. 16.

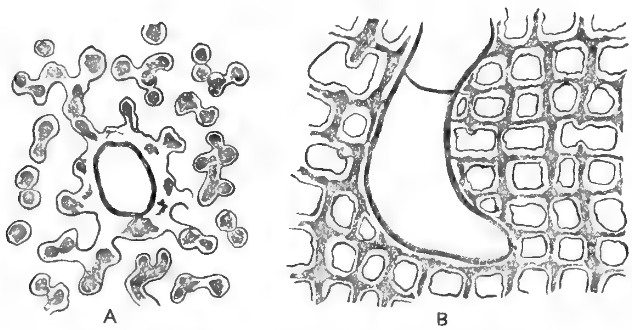


FIG. 16.—A. Tangential section of *Hermatostroma Schlüteri*, n. sp., enlarged twelve times. B. Vertical section of the same, similarly enlarged. Both sections intersect one of the large thin-walled tubes which are found at intervals in this species.

One of the most singular features in *Hermatostroma Schlüteri* is to be found in the fact that each successive stratum of the massive cœnosteum is traversed by a series of short, wide, flexuous tubes, directed vertically to the concentric laminæ, and apparently terminating inferiorly by closed ends, while they open above on the surfaces of the laminæ by large rounded apertures. Thin sections (Fig. 16) show that these tubes have thin proper walls of their own, and have occasional internal tabulæ; and they might therefore be supposed to be adventitious structures. That they belong, however, to the Stromatoporoid in which they are found seems to be sufficiently shown by their comparatively regular development, by their being uniformly present in all parts of the mass and at all levels, and by their opening on the surface by definite apertures, often placed on rounded "mamelons." By the fact that they have no connection with one another, it is rendered certain that they cannot belong to embedded colonies of either *Aulopora* or *Syringopora*. It is difficult to see what these tubes can be, if they did not serve for the lodgment of the reproductive zoöids.

There is in many respects a close relationship between *Hermatostroma* and *Idiostroma*, the general arrangement of the skeletal tissue being very similar in the two genera. The system of tubuli in the skeleton-fibre is, however, greatly more

developed in the former than in the latter. Moreover, the tabulate zoöidal tubes of *Idiostroma* have only a very feeble representation in *Hermatostroma*, while the axial tabulate tube of the typical forms of *Idiostroma*, with its lateral tabulate offshoots, is a feature apparently unknown in the present genus.

Genus STACHYODES, *Bargatzky.*

('Zeitschr. der deutschen Geol. Ges.,' Jahrg., 1881, p. 688.)

Cœnosteum having typically the form of branched cylindrical stems, which are rooted basally, and terminate distally in rounded ends. The skeletal tissue is of the reticulated type, neither the radial pillars nor the concentric laminæ being developed as distinct structures. The skeleton-fibre is minutely tubulated, the tubuli running parallel with the zoöidal tubes. Definite zoöidal tubes, which are sparingly tabulate, are present and open on the surface by rounded apertures. In the centre of the stems is a large axial tube, which is crossed by numerous curved or straight tabulæ, and which gives off diverging lateral branches, which are also tabulate. No astrorhizæ appear to be present.

It seems probable that one of the forms which Goldfuss included under the name of *Stromatopora polymorpha*, namely, the form which Bargatzky named *S. polyostiolata*, is really a *Stachyodes*, as shown by the minute structure of the skeleton of the original specimen. The above definition, however, is based upon the singular type which Bargatzky (loc. cit. *supra*) has described under the name of *Stachyodes ramosa*. Having examined a large series of specimens of this, which I have obtained from the Devonian Rocks of Devonshire and of Germany, I see no reason to doubt that it is really the previously described *Stromatopora* (*Caunopora*) *verticillata*, M'Coy (' Brit. Pal. Foss.,' p. 66,) under which specific title it will therefore have to remain. The cœnosteum in this form consists of cylindrical stems, generally about a centimetre in diameter, which commonly branch, and which terminate in rounded ends (Plate VIII, fig. 9). In its general aspect the fossil closely resembles the dendroid species of *Pachypora*, Lindst., a resemblance which is increased by the fact that the surface is extensively covered with the rounded apertures of the zoöidal tubes. Parts of the surface, however, very commonly do not exhibit these apertures, but, on the contrary, are occupied by a thin investing calcareous membrane (Plate VIII, fig. 12). Judging from the analogy of *Amphipora ramosa*, it is not improbable that the development of this membrane is connected with the production of reproductive zoöids in " ampullæ." Though the dendroid form is the commonest, I have seen examples which form irregular masses. In the centre of the stem runs a principal axial tube (Plate VIII, figs.

10, 11) which is crossed by more or less numerous curved tabulæ, and which gives off lateral tabulate branches. Judging from the few examples which I have seen in which the ends of the branches are perfectly preserved, it would appear that the main axial tube terminates at the end of each branch in one, two, or more large-sized apertures. The lateral divisions of the main axial tube, however, subdivide and give off numerous small zoöidal tubes, which are continued to the surface, and which seem to be only sparsely furnished with tabulæ. Growth of the cœnosteum is effected by the formation of successively formed convex layers, which are much thicker over the growing ends of the branches than elsewhere (Plate VIII, fig. 10), and which give rise in thin sections to a series of curved concentric lines, the convexities of which are turned towards the distal end of the colony. There are, however, no true concentric laminæ, nor can any definite radial pillars be recognised. The skeleton is continuously reticulated, and the sclerenchyma is everywhere traversed by innumerable delicate tubuli, which run parallel to the zoöidal tubes (Plate VIII, fig. 14). In tangential sections (Plate VIII, fig. 13), the cut ends of these tubuli are seen, sometimes as minute rounded apertures, sometimes as dark dots (Plate XI, figs. 5 and 6), according as the tubuli are empty or are infiltrated with oxide of iron. Though in the main running parallel with the zoöidal tubes, the tubuli frequently branch and anastomose with one another.

Stachyodes verticillata shows some curious points of resemblance to certain of the *Stylasteridæ*. Thus, longitudinal sections of *Distichopora*, taken in the median plane of the cœnosteum and dividing the pore-tubes lengthways, show phenomena in many ways resembling those presented by *Stachyodes* (Plate IX, fig. 5). This resemblance is particularly marked as regards the microscopic tubuli of the skeleton-fibre of both these types. If *Stachyodes* stood quite alone there might be some ground for regarding it as an ancient type of the *Stylasteridæ*. It has, however, strongly marked relationships to *Idiostroma*, Winch., and through this with the whole group of the *Stromatoporidæ* proper. It agrees entirely with the cylindrical types of *Idiostroma* as regards the possession in the interior of the stems of a tabulate axial tube, from which spring secondary lateral tubes, which are also tabulate. In fact, the essential point by which it is separated from *Idiostroma* is only the characteristic tubulation of the skeleton-fibre.

Genus AMPHIPORA, *Schulz.*

('Die Eifelkalkmulde von Hillesheim,' p. 89, 1883. Reprinted from the 'Jahrb. der königl. preuss. geol. Landesanstalt' for 1882.)

The cœnosteum in this genus is in the form of slender cylindrical stems, which may or may not branch in a dichotomous manner. In the centre of the cœnosteum and running its entire length is a wide axial tube, which is intersected by transverse or funnel-shaped tabulæ. The general skeletal tissue is continuously reticulated, of the type of that of the *Stromatoporidæ,* but apparently compact instead of being minutely porous. Distinct but irregular zoöidal tubes radiate outwards from the axial tube to open on the surface by definite apertures. The surface sometimes shows the apertures of the zoöidal tubes, surrounded by vermiculate or tuberculated margins, but at other times the cylindrical cœnosteum is surrounded by a zone of large-sized lenticular vesicles, which are enveloped by a delicate, apparently imperforate calcareous membrane.

So far as known, the genus *Amphipora* is represented by one species only, viz. the form described by Phillips under the name of *Caunopora ramosa* ('Fig. and Descript. Pal. Foss.,' p. 19). This remarkable species occurs in vast numbers in the Devonian Rocks of Germany and Devonshire, apparently occupying in the former region, as probably in the latter also, a definite horizon in the upper portion of the Middle Devonian series (the "Ramosa-Bänke" of Schulz). In its dendroid cœnosteum (Plate IX, fig. 1), *Amphipora ramosa,* Phill., resembles *Stachyodes verticillata,* and this resemblance is further increased by the fact that in both these types the skeleton is traversed by a principal axial tabulate tube (Plate IX, figs. 2 and 4). The skeleton-fibre of *Amphipora ramosa* exhibits, however, no traces of the microscopic tubulation which is so characteristic of even the smallest fragment of the skeleton of *Stachyodes.* In fact, the skeleton-fibre of *Amphipora* appears to be quite compact, though there are grounds for thinking that this is perhaps only the result of mineralisation and that the fibre may be to some extent porous. The most remarkable peculiarities of *A. ramosa* are, however, connected with the condition of its surface. In examining a large series of specimens, one is at once struck by the fact that many individuals have the surface covered with the rounded apertures of the zoöidal tubes, which are bounded by tuberculate margins and which give to the fossil very much the appearance of a small species of *Pachypora.* On the other hand, many other individuals (Plate IX, fig. 1) have the surface entirely covered by a thin, imperforate, calcareous membrane, which gives them very much the aspect of the stems of such Corals as *Lithostrotion junceum* or

Diphyphyllum stramineum, Bill. Very commonly a portion of a single stem will be covered in this way by a smooth calcareous envelope, while other portions, from natural or artificial deficiency of the membrane in question will exhibit the apertures of the zoöidal tubes. In transverse sections of such specimens as possess this membranous covering we find that it is not applied directly to the poriferous surface below, but that between the two are developed numerous large-sized lenticular vesicles, the general appearance of which is not unlike the vesicles of such Corals as the *Cystiphylla* (Plate IX, fig. 3). To begin with, I was under the impression that these " marginal vesicles " were structures of constant occurrence and that their non-existence in certain specimens was only due to the fact that the peripheral vesicles had been decorticated prior to fossilisation. I am, however, now satisfied that this is not the case, but that there exist under *Amphipora ramosa* two distinct groups of specimens, those of the one group, seemingly the most numerous, exhibiting a poriferous and vermiculate surface; while those of the other group have their original surface surrounded by a zone of vesicles which are in turn enveloped by a thin calcareous pellicle. The only conjecture which I can offer as to the nature of these " marginal vesicles " is that they are reproductive in function, and that they correspond with the "ampullæ" of the *Stylasteridæ*. This view would not only explain the fact that these vesicles were not universal in their occurrence in *A. ramosa*, but would also throw some light upon the otherwise inexplicable phenomenon that various Stromatoporoids have so commonly portions of the surface covered by a kind of calcareous pellicle.

VI. THE NATURE OF "CAUNOPORA."

The singular fossils for which the generic names of " *Caunopora*," Phill., and " *Diapora*," Barg., have been proposed are known, to their cost, by all students of the Stromatoporoids. They have proved a fertile source of differences of opinion; and these differences are important, since the conclusions which are to be formed as to the structure and relations of the whole group of the Stromatoporoids necessarily depend largely upon the views which may be held as to the nature of the so-called " *Caunoporæ* " and " *Diaporæ*." As is well known, the fossils to which these names have been given, resemble in all essential respects the ordinary Stromatoporoids, except that the cœnosteum is traversed by numerous *thick-walled* tubes, which are directed at right angles to the concentric laminæ of the fossil, and which open by definite rounded apertures upon its surface. Sometimes these tubes—which may in the meanwhile be conveniently called " Caunopora-tubes "—have simply a thin,

but quite definite proper wall, either alone or with but a very thin secondary lining. More commonly, the proper wall is strengthened by a dense secondary deposit of light-coloured sclerenchyma, which may nearly obliterate its internal cavity (Plate X, fig. 2). The tubes are attached inferiorly to irregular horizontal stolons, which sometimes clearly have a proper wall, but which at other times seem to be bounded only by the general tissue of the Stromatoporoid. The tubes further give out lateral horizontal tubes, which may simply open into adjoining tubes, or which may ultimately bend upwards and give origin to new vertical tubes. Superficially, the "Caunopora-tubes" terminate in rounded thickened apertures, which are flush with the general surface, or project very slightly above it. In the few specimens in which the tubes appear to be prolonged above the surface at all, it is probable that the fossil has been partially decorticated; but the horizontal connecting-processes certainly seem to occasionally lie above the last-formed layer of the Stromatoporoid (Plate X, fig. 3). As to whether or not there exists any communication between the "Caunopora-tubes" and the interlaminar spaces and zoöidal tubes of the enveloping Stromatoporoid, it seems impossible to arrive at present at any absolutely positive conclusion. In most cases there certainly seems to be no such communication. On the other hand, thin sections occasionally show phenomena which would lead to the belief that the horizontal connecting-tubes *may* open into the adjoining zoöidal tubes, or that the main "Caunopora-tubes" themselves sometimes open inferiorly into the interlaminar spaces of the Stromatoporoid; but it is probable that the phenomena in question are delusive.

As regards their internal structure, the "Caunopora-tubes" are probably always *tabulate*. It is true that in a number of specimens "tabulæ" cannot be detected, but this is probably the result of mineralisation, as I have rarely failed to detect these structures in well-preserved examples of all the forms of "*Caunopora*." The tabulæ may be simply horizontal, or curved, but they are more commonly partially funnel-shaped, a number of vesicular tabulæ being placed on one side or on both sides of the tube. Hence cross-sections of the tubes present appearances almost exactly similar to those seen in corresponding sections of the corallites of *Syringopora*, and sometimes in similar sections of *Aulopora*. Very often, the same "Caunopora-tube" is partially furnished with flat tabulæ, and partially with funnel-shaped tabulæ. As a general rule I have failed to detect the existence of *septal spines* in the "Caunopora-tubes;" and I am not aware that these structures have been clearly recognised as occurring in any instance by previous observers. I have never found any satisfactory indications of septa in any of the "*Caunoporæ*" of the British Devonian Rocks, but it may well be that this is the result of the extent to which most of the Devonshire specimens have been altered by fossilisation. I have also not succeeded in detecting such structures in a large number of specimens from the Devonian Rocks of Germany, where the minute structure is very well

preserved. It is therefore extremely probable that the tubes of many of the "*Caunoporæ*" and "*Diaporæ*" are really destitute of anything of the nature of septa. On the other hand, I have recently found a number of "*Caunoporæ*" in the Devonian Rocks of the Eifel, in which the "tubes" are furnished with well-preserved and quite unmistakeable septal spines. In such cases the septal spines are arranged in vertical rows in the interior of the tubes, eight of such rows being apparently the general number. The spines are altogether of the type of these structures, as seen in many species of *Favosites* or in *Syringopora*. They have the form of blunt calcareous spines (Fig. 17), which fall short of the centre of the tubes, and

FIG. 17.

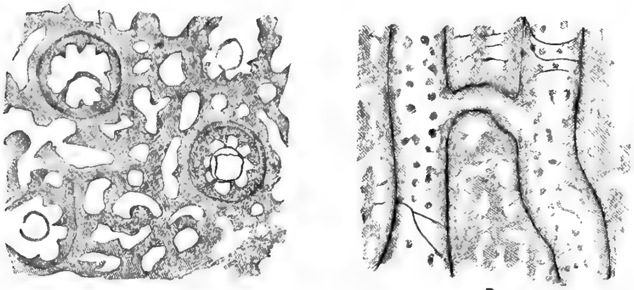


FIG. 17.—Sections of a species of *Stromatopora*, from the Devonian Limestone of Gerolstein, enlarged twelve times, showing "Caunopora-tubes" with septal spines. A. Tangential section. B. Vertical section

are often quite marginal. They are most easily recognised, as a rule, in longitudinal sections, in which they are transversely divided near their bases, and appear in the interior of the tubes as rows of dark round spots (Fig. 17, B). I may add that in a specimen of "*Caunopora*" from the Corniferous Limestone of Ontario, which Dr. Hinde was so good as to submit to me, I have found similar but even more largely developed septal spines.

Another point in which great variations exist among the so-called "*Caunoporæ*" is as to the mode of growth of the tubes. In some specimens, which, however, are by no means typical ones, the "Caunopora-tubes" are very irregular in their growth, being often far apart, and not extending their vertical growth to any great distance from the horizontal stolons to which they are attached. In such specimens, the "Caunopora-tubes," if divested of the enveloping Stromatoporoid, might fairly enough represent an ordinary *Aulopora* colony, in which the tubes had grown to a much greater height than is usual in the genus *Aulopora*, and had also become here and there connected by an occasional cross-tube. This is the condition of things, for example, in the specimen from the Corniferous Limestone just alluded to. In the great majority of the "*Caunoporæ*," however, the tubes are placed close together, and usually at tolerably regular intervals, and they grow straight upwards for very considerable distances. Owing to the fact that it is not possible to make

any vertical sections which shall intersect any given tube along its entire length, it is not possible to assert positively that the individual tubes of the "*Caunoporæ*" are continued through the entire thickness of the larger examples without interruption. In laminar specimens of "*Caunopora*" it seems almost certain that the majority of the tubes are continued straight from the base of the organism to the surface, without any interruption, merely giving off horizontal connecting-processes to adjoining tubes at intervals. In such specimens I have often traced a single tube, without a break, through a vertical thickness of an inch or more. In the more massive specimens, which often reach several inches in thickness, I have little doubt that the tubes also run for very long distances without interruption, though I am not able to say that they are continued from the base to the surface. [I have traced a single tube for over two inches.] In such specimens, therefore, the "Caunopora-tubes," if divested of the surrounding tissue, would more nearly resemble a colony ot *Syringopora* than one of *Aulopora*. They would, however, differ from any ordinary *Syringopora* in the regularity with which they are spaced, and, still more, in their often very minute size.

In other specimens, again, parts of the organism may be charged with "Caunopora-tubes," while they may be wanting, or very sparsely developed, in other parts of the same. In other cases, again, the "*Caunopora*" assumes a cylindrical shape, and then the tubes radiate outwards in all directions to open on the surface of the specimen. A modification of this is seen in some specimens where the organism consists of a series of parallel cylinders united by a larger or smaller amount of interstitial tissue. In such cases, each cylinder is generally traversed by its own set of "Caunopora-tubes," radiating outwards from its central line.

Another important consideration in the case of the "*Caunoporæ*" and "*Diaporæ*" is that of the nature of the Stromatoporoid in which the "Caunopora-tubes" are enveloped. I have examined many hundreds of these fossils, but it has not been in more than perhaps a dozen instances that I have met with anything that could be properly called a "*Caunopora*" or "*Diapora*" unless the enveloping Stromatoporoid has belonged to the "Milleporoid" section of the Stromatoporoids, *i. e.* to that section in which the skeleton is of the more or less completely reticulated type. In fact, almost all the "*Caunoporæ*" and "*Diaporæ*" belong, as regards the tissue of the enveloping Stromatoporoid, to the genera *Stromatopora*, Goldf., and *Stromatoporella*, Nich., and it was upon the difference in the structure of the skeleton in these two genera that Bargatzky founded his genus *Diapora*, as distinct from *Caunopora*, Phill. Until recently, I should have said that *all* specimens of "*Caunopora*" and "*Diapora*" belonged, as regards the enveloping Stromatoporoid, to the genera *Stromatopora* and *Stromatoporella*. Dr. Hinde has, however, shown me a specimen of a "*Caunopora*" from the Corniferous Limestone of Canada, in which the enveloping Stromatoporoid is referable to the genus *Clathrodictyon*.

Mr. Champernowne has, further, shown me a specimen of *Actinostroma*, from the Devonian Rocks of Devonshire, in which "Caunopora-tubes" are developed. Lastly, I have myself recently collected a number of specimens of "*Caunoporæ*" from the Silurian Rocks of Oesel, in which the enveloping Stromatoporoid belongs to a peculiar group of forms intermediate between *Clathrodictyon* and *Rosenella*.

It should be borne in mind, however, that there occasionally occur specimens which are penetrated by isolated or quite irregular tubes which have internally much the same structure as "Caunopora-tubes," from which, indeed, they could not be morphologically distinguished, but which should not be considered as being true "*Caunoporæ*" or "*Diaporæ*." In such cases, the tubes are generally of large size, are entirely irregular in their growth and distribution, run usually more or less horizontally or obliquely, and sometimes are exposed over parts of the surface. It seems safe to set down all such specimens as cases in which some Stromatoporoid has more or less completely enveloped in its growth some Syringoporoid or Auloporoid Coral. I do not mean by this to imply that the *true* "*Caunoporæ*" may not also be due to the combined growth of a Stromatoporoid with some Syringoporoid or Auloporoid Coral; only in that case, as will be shown later on, it is necessary to suppose that the enveloped Coral has undergone certain striking changes in its normal mode of growth, whereas in the specimens just alluded to the embedded Coral exhibits nothing distinctive or peculiar.

One other important general point about the "*Caunoporæ*" and "*Diaporæ*" remains to be noticed, and it is of the highest significance. I have found, namely, that all those Stromatoporoids, which are known to me as *habitually* giving rise to "*Caunoporæ*" and "*Diaporæ*," occur both with and without the embedded "Caunopora-tubes." That is to say, while, as a general rule, only certain particular species of Stromatoporoids occur in the condition of "*Caunoporæ*" or "*Diaporæ*," the same species can always be shown to exist *without* the embedded tubes which characterise these two so-called genera. I shall deal more fully with this point later on. All that it is in the meanwhile necessary to insist upon is that this discovery would seem to render it certain that the "Caunopora-tubes"—whatever the true nature may be—are not structures characteristic of particular *species* of Stromatoporoids. On the contrary, they occur only in certain individuals of those species in which they are found at all, and they are wanting in other individuals of the same species. It follows from this, *a fortiori*, that the presence of "Caunopora-tubes" cannot be employed as a character distinctive of certain *genera* of the Stromatoporoids. We must therefore abandon the names *Caunopora*, Phill., and *Diapora*, Barg., as the titles of genera.

The main details of the history of opinion as to *Caunopora* may be told in a few sentences. The genus *Caunopora* was originally founded by Phillips ('Pal. Foss. of Cornwall, &c.,' p. 18, 1841) for two different forms, viz. *C. placenta*,

Lonsd., and *C. ramosa,* Phill. The latter of these has been seen not to be a "*Caunopora*" at all, but to be the type of the genus *Amphipora,* Schulz. The former is the *Coscinopora placenta* of Lonsdale, and it would be difficult or impossible, from the figures and descriptions of both Lonsdale and Phillips, to identify it precisely with any particular one of the three or four commoner kinds of "*Caunoporæ*" which occur in the Devonian Rocks of Devonshire. It would, at any rate, in my opinion, be inexpedient to attempt to retain the name of "*placenta*" as a *specific* title, unless *Caunopora* were also to be retained as a *genus*. My reason for this conclusion is that the presence of "Caunopora-tubes" in the fossil was, of course, the essential feature selected by Lonsdale and Phillips as characterising their *Caunopora placenta* as a *species*, whereas these tubes occur in all the so-called *Caunoporæ*, and their presence cannot, therefore, be employed to characterise a species.

As early as 1844, Professor Ferdinand Roemer expressed the opinion ('Das rheinische Uebergangsgebirge') that *Caunopora*, Phill., was merely based upon examples of Stromatoporoids, which in the course of growth had enveloped colonies of *Syringopora*, and that the genus consequently must fall to the ground. To this view Roemer has always adhered, so far as concerns the belief that "Caunopora" has no existence as a single organism; but he has so far modified his original view ('Geol. Mag.,' New Ser., Dec. ii, vol. vii, p. 343, 1880) that he now regards *Aulopora* rather than *Syringopora* as the Coral which is associated with Stromatoporoids in the production of "*Caunopora*" colonies.

In the series of valuable papers which he has published on the Stromatoporoids Mr. Carter was at first disposed to accept "Caunopora" as an independent organism; but he subsequently abandoned this view, and expressed the opinion that, as previously asserted by Roemer, the *Caunoporæ* were the result of the commensalism of a Stromatoporoid and a Coral ('Ann. and Mag. Nat. Hist.,' Ser. 5, vol. iv, p. 101, 1879). At a still later date, while retaining this view as to the commensalism of *Caunopora*, Mr. Carter expressed the opinion that the Coral which was thus associated with Stromatoporoids was rather to be regarded as *Syringopora* than as *Aulopora*, since infundibuliform tabulæ could be occasionally recognised in the tubes ('Ann. and Mag. Nat. Hist.,' Ser. 5, vol. vi, p. 339, 1880.)

Mr. Champernowne, whose opinion upon any subject connected with the Devonian Stromatoporoids is of the greatest value, also arrived at the conclusion that the "commensal theory" was probably the true one, and has consistently opposed the view that "*Caunopora*" and "*Diapora*" are *genera* of Stromatoporoids.

On the other hand, many observers have at various times maintained views as to the nature of *Caunopora* opposed to the preceding. It has, namely, been held by many authorities that the thick-walled tubes of "*Caunopora*" are not foreign to the Stromatoporoid in which they are found, but truly belong to it, and that the

genus is therefore a valid one. To mention only the most recent writers on this subject, this view has been maintained by Dr. August Bargatzky ('Die Stromatoporen des rheinischen Devons,' 1881), and by Dr. Carl Riemann ("Die Kalke des Taubensteins bei Wetzlar und ihre Fauna," 'Neues Jahrb. für Min. Geol. und Pal.,' 1884). Dr. Bargatzky, indeed, not only supports the validity of the genus *Caunopora*, Phill., but founds the new genus *Diapora* for certain "Caunopora" colonies in which the "ground-mass" exhibits radial pillars and concentric laminæ, instead of being simply reticulate, as it is in the true "*Caunopora*" of Phillips, as understood by Bargatzky.

For my own part, I must frankly admit that my views have always been in favour of the validity of "*Caunopora*," as comprising independent organisms. In pursuit of the present inquiry, however, I have had to make a microscopic examination of a very extensive series of specimens of "*Caunopora*" and "*Diapora*" from the Devonian Rocks of Devonshire, Germany, France, and North America, and I have been driven to the conclusion that these names do not correspond with generic divisions, but that the fossils so called are in reality occasional *conditions* of certain particular species of Stromatoporoids. This does not, however, necessarily involve the acceptance of the "commensal theory" of "*Caunopora*," of which Roemer is the originator, and in which he has been followed by Carter and Champernowne—the theory, namely, that the fossils upon which "*Caunopora*" is based are really the result of the commensalism of certain types of Stromatoporoids with certain types of Corals. The problem as to the precise nature of the tubes of "*Caunopora*" has, indeed, proved to be one of such extreme difficulty that it will be best to give here a kind of summary of the arguments for and against the different views which might be taken as to this subject, without committing myself finally to any one theory as opposed to the others. In so doing there are three principal theories which I shall pass in review, viz.:—(1) The view that "*Caunopora*" and "*Diapora*" are *genera* of Stromatoporoids; (2) the theory of Roemer that "*Caunopora*" and "*Diapora*" are the result of the commensalism of certain Stromaporoids with certain Corals; and (3) the theory that the "tubes" of "*Caunopora*" and "*Diapora*" belong to the organism in which they are found, but that they represent structures which are only developed in certain colonies or in certain individuals, and that these names, therefore, merely indicate a *state* of certain Stromatoporoids.

I. *Caunopora and Diapora as Genera.*

The theory that *Caunopora*, Phill., and *Diapora*, Barg., are *genera* of Stromatoporoids may, in the light of presently known facts, be dismissed with comparative brevity. So long as it remained unknown with what particular types of Stromato-

poroids "Caunopora-tubes" were associated, it was a not unreasonable conclusion that the forms possessing these singular structures were really distinct genera. Bargatzky was the first observer who directed his attention specially to the minute structure of the tissue enveloping the tubes; and he showed, quite rightly, that this tissue is sometimes of the completely reticulated type, while at other times the reticulation is incomplete. On this difference—which is really the difference between *Stromatopora*, Goldf., and *Stromatoporella*, Nich.—he based his separation of *Diapora*, Barg., from *Caunopora*, Phill. As already pointed out, it would appear that there are only certain particular types of the Stromatoporoids which habitually form "Caunoporoid" colonies, and that other common and well-known types rarely or never do so. For example, the species of *Actinostroma*, which occur in such vast numbers in the Devonian Rocks of Britain and Germany, seem hardly ever to form "*Caunoporæ*." They very commonly envelop Corals of different kinds in the course of their growth; but with the exception of a single specimen in the collection of Mr. Champernowne, I have never met with an example of the genus associated with the regular "Caunopora-tubes." No *Labechia* has ever been recorded as giving rise to "*Caunopora*" colonies, though the cœnosteum in this genus also quite commonly grows round and envelops Corals or other foreign organisms. Similarly, the species of *Clathrodictyon* are almost never observed with associated "Caunopora-tubes." With very few exceptions, all the "*Caunoporæ*" and "*Diaporæ*" which I have examined belong, as regards the investing Stromatoporoid, to the family of the *Stromatoporidæ*, and to one or other of the two genera *Stromatopora*, Goldf., and *Stromatoporella*, Nich. Moreover, all the species of these two genera which are of common occurrence as "*Caunoporæ*" and "*Diaporæ*," occur also *without the embedded tubes*, the two "states" of each species being often found side by side in the same locality. The species of *Stromatopora* and *Stromatoporella* which are most commonly concerned in the production, respectively, of "*Caunoporæ*" and "*Diaporæ*" are the following:

(*a*) *Stromatopora concentrica*, Goldf. (Plate XI, figs. 16 and 17, respectively with and without "Caunopora-tubes").

(*b*) *Stromatopora Hüpschii*, Barg., sp. (Plate X, figs. 8—12, with the "Caunopora-tubes;" woodcut, Fig. 6, without the tubes).

(*c*) *Stromatopora bücheliensis*, Barg., sp. (Plate X, figs. 6 and 7, with the "Caunopora-tubes;" woodcut, Fig. 6, without the tubes).

(*d*) *Stromatopora Beuthii*, Barg., sp.

(*e*) *Stromatoporella laminata*, Barg., sp. (Plate X, figs. 1—4).

(*f*) *Stromatoporella eifeliensis*, Nich.

The species of *Stromatoporella* have not yet been worked out, and I do not know whether there are any species of this genus which never form "*Diapora*" colonies. I have not, however, so far, found the type-species of this genus, viz. *S. granulata*,

Nich., to be associated with "Caunopora-tubes." On the other hand, there are various species of the genus *Stromatopora* which, so far as our present knowledge goes, never give rise to "*Caunopora*" colonies. Thus, I have never seen any examples of "*Caunopora*" colonies in the case of the Silurian *Stromatoporæ*, such as *S. typica*,[1] Rosen, *S. Carteri*, n. sp., and *S. discoidea*, Lonsd., though the first of these is the commonest of all the Silurian Stromatoporoids in this country. So far as I know, indeed, the Silurian Rocks of Britain have as yet yielded no "*Caunoporæ*." It has, however, been pointed out by Professor Ferdinand Roemer ('Geol. Mag.,' 1880, p. 345) that the Silurian pebbles of the Drift of Holland and North Germany sometimes yield specimens of "*Caunoporæ*." Of this nature is the fossil described by Goldfuss ('Petref. Germ.,' vol. i, p. 113, Taf. 38, fig. 13) as *Syringopora filiformis* and subsequently described by Roemer himself as *Heliolites interstincta* ('Diluvial Geschiebe von Sadewitz,' p. 24, Taf. 4, fig. 2 *c*). I have also recently collected in the Silurian Rocks (Upper Oesel Group) of Oesel a number of remarkable specimens of "*Caunoporæ*." These present, however, certain special peculiarities of their own, one of the most important of these being that the enveloping Stromatoporoids appear to be related to the genus *Clathrodictyon*, the associated species of *Stromatopora* being seemingly free from "Caunopora-tubes."

Upon the whole, considering that the embedded tubes constitute the essential feature upon which *Caunopora*, Phill., and *Diapora*, Barg., were founded, the facts above recounted would seem to render it absolutely certain that these names cannot be retained as names of *genera*. To retain these names would lead us into the position of having a series of forms of *Stromatopora* and *Stromatoporella* which could only be separated from a parallel series of forms of *Caunopora* and *Diapora* by the fact that the latter possessed embedded tubes, the structure of these tubes being in all these species essentially the same. As this position appears to me to be a quite untenable one, I shall abandon *Caunopora*, Phill., and *Diapora*, Barg., as genera of the Stromatoporoids ; since the attempt to reconstruct these genera by the omission of the "tubes" from the list of their distinctive characters could only lead to confusion.

[1] I have recently collected in the Silurian Limestones of Hoheneichen, in Oesel, a remarkable specimen of *Stromatopora typica*, Rosen, which has the general aspect of a "*Caunopora*," with unusually large tubes. In this specimen, however, the embedded tubes differ entirely in their structure from those of all the ordinary "*Caunoporæ*." Not only do they unquestionably belong to an organism foreign to the Stromatoporoid in which they are enveloped, but they belong to a very peculiar type of Rugose Corals with which I am not otherwise acquainted.

II. *The Theory of the Commensalism of Caunopora and Diapora.*

In discussing Prof. Roemer's theory of the "commensalism" of "*Caunopora*" and "*Diapora*," I shall, in the first place, review generally the arguments against the theory and those in favour of it. In the second place, it will be necessary to discuss the question whether, if the theory of commensalism be accepted, the "Caunopora-tubes" are referable to *Syringopora*, or whether they belong to *Aulopora*.

(A) *General Arguments against Commensalism.*—The following, stated briefly and in a summary form, are the principal facts and considerations which tell against any theory of the commensalism of "*Caunopora.*" It should be premised that all those cases where Stromatoporoids demonstrably envelop different kinds of Corals are here left out of sight. All we have to deal with here are the *typical* "*Caunoporæ*" and "*Diaporæ,*" in which we cannot at present *demonstrate* commensalism. With regard to all such specimens—and they are very numerous—it may be taken for granted, with our present knowledge, that if the organism be the result of the commensalism of a Coral and Stromatoporoid, the former must belong to *Syringopora* or *Aulopora*, or to some closely allied type. We are not, at any rate, acquainted with any Palæozoic Corals, except the species of these two genera or of closely related types, the internal structure of which is such as to permit of our supposing that the "Caunopora-tubes" might belong to them.

1. In the first place, colonies of *Aulopora* are often found associated in different ways with Stromatoporoids, and yet not giving rise to "*Caunoporæ*" or "*Diaporæ.*" Thus, in the Wenlock Limestone of Britain nothing is commoner than to find *Aulopora* colonies spreading over the upper or under surfaces of Stromatoporoids, and even sometimes in part enveloped in these; but in an examination of two or three hundred of such specimens I have not detected a single one in which the Stromatoporoid had completely enclosed the Coral, or in which the latter had been induced to lengthen its tubes or to alter in any way its normal mode of growth. On the other hand, in the Devonian Strata I have often noticed tubes apparently belonging to *Auloporæ*, or to some of the types which have been placed under *Syringopora*, completely immersed in Stromatoporoids, and nevertheless not giving rise to "Caunoporæ;" the growth of the embedded Coral being altogether irregular and showing none of the peculiar characters of the latter.

2. Again, there are extensive groups of rocks in which all the conditions required, on the theory of commensalism, for the production of "Caunoporæ" are present, and yet the fossils so called are unknown, or are extremely rare. Thus, as just noted, the Wenlock Limestone of Britain contains a vast abundance of Stromatoporoids (including three species of the genus *Stromatopora* itself) along with

numerous examples of both *Aulopora* and *Syringopora;* and yet I have never found a single example of either "*Caunopora*" or "*Diapora*" in it, nor do I know that one has ever been found.[1] Another but not so striking case is that of the Corniferous Limestone of North America, in which we find a remarkable profusion of species of *Syringopora*, and to a less extent of *Aulopora*, existing with great numbers of Stromatoporoids; and yet "*Caunoporæ*" and "*Diaporæ*" are exceedingly rare.

3. The converse of this also holds good. That is to say, there are strata in which "*Caunoporæ*" and "*Diaporæ*" are very abundant, and in which *Aulopora* and *Syringopora* may be very rare. This is most marked in the case of the Devonian Limestones of Devonshire, in which "*Caunoporæ*" are extraordinarily abundant, whereas species of *Aulopora* or of *Syringopora* (unless they are supposed to be nearly all "commensals") are hardly known, and are certainly very rare. A partial explanation of this may doubtless be found in the difficulties which attend the collection of fossils from these strata otherwise than in polished slabs; but this explanation would not apply to cases like the Devonian Limestones of Gerolstein, in the Eifel, where "*Caunoporæ*" and "*Diaporæ*" are very common, whilst *Auloporæ* are not particularly abundant, and *Syringoporæ*, if they occur at all, are extraordinarily rare.

4. If we accept the theory of the commensalism of "*Caunopora*" and "*Diapora*," we must suppose that the production of the fossils so named involves something very much more than mere *envelopment*. Perhaps all the forms of the Stromatoporoids—save such abnormal types as *Amphipora* and *Beatricea*—occur *occasionally* encrusting or enveloping foreign organisms. We should therefore expect that *any* type of the Stromatoporoids might sometimes be found in the "Caunopora-state." On the contrary, it is only the Stromatoporoids of one particular group which seem habitually to give rise to "*Caunoporæ*" and "*Diaporæ*;" and it is only certain species in this group which appear to do so. Moreover, the forms which *do* produce such colonies are mostly non-encrusting types, furnished with a basal epitheca.

5. Moreover, supposing that "*Caunoporæ*" and "*Diaporæ*" are the result of the associated growth of a Stromatoporoid and a Coral, there are no Palæozoic Corals which have even a general correspondence as regards their internal structure with the "tubes" of these fossils, except the Auloporoid and Syringoporoid Corals.

[1] As before mentioned, I have recently found a number of specimens of "*Caunopora*" in the Upper Silurian Limestones of Oesel, these being the only Silurian "*Caunoporæ*" that I have ever seen. At one locality (Kattri-pank) these "*Caunoporæ*" are associated with numerous examples of *Syringopora bifurcata*, Lonsd. (= *S. reticulata*, His.); and I thought at first that the former might easily prove to be merely colonies of the latter living commensally with Stromatoporoid colonies. A microscopic examination of both, however, has satisfied me that in this particular instance the embedded tubes of the "*Caunoporæ*" are certainly *not* referable to this particular species of *Syringopora*, as they differ from the latter both in size and in their internal structure.

But there are no known species of either *Aulopora* or *Syringopora*, the colonies of which, in their normal habit and mode of growth, would correspond in any *precise* way with the aggregate of tubes of a "*Caunopora*" or "*Diapora*," as these latter would be seen when divested of the Stromatoporoid in which they are enveloped. I shall enter into this subject at greater length in discussing the special claims of either *Aulopora* or *Syringopora* to be regarded as concerned in the production of "*Caunoporæ*." In the meanwhile it is enough to point out, that whether we select *Aulopora* or *Syringopora* as the Coral associated with a Stromatoporoid to form "*Caunopora*" colonies, or whether we allow both to play this part, we are alike compelled to suppose that the Coral, when living under these conditions of life, entirely modifies its normal habits and mode of growth. This seems to me to be the only way of accounting satisfactorily for the peculiarities of the tubes of a "*Caunopora*" colony, if we suppose these tubes to belong to any known species of *Aulopora* or *Syringopora*.

6. Lastly, if the theory of the commensalism of "*Caunopora*" be accepted, we must admit not only that several species of Stromatoporoids are liable to form such colonies, but also that at least two or three species of Corals are concerned in the process. For "*Caunoporæ*" differ from one another, not only as to the structure of the "ground-mass" of the fossil, but also as to the size and other characters of the embedded tubes.

(B) *General Arguments in favour of Commensalism.*—The above are the principal difficulties which have to be confronted, if we accept the theory of the commensalism of "*Caunopora;*" and they are so numerous and so weighty as to form, in my opinion, an ample justification for those who have hitherto hesitated to admit the correctness of the theory. On the other hand, the following are the principal arguments, of a merely *general* nature, which support the theory of commensalism:

1. The general aspect of the tubes of "*Caunopora*" and "*Diapora*" is extremely like that of the tubes of the Auloporoid and Syringoporoid Corals; sometimes resembling *Auloporæ;* at other times making a close approach to the *Syringoporæ*.

2. The tubes have definite thickened *walls* of their own, quite distinct as a rule from the tissue of the investing Stromatoporoid (Plate X, figs. 1, 2, 6, 7, 8, 9). In all cases, the tubes are uniformly and universally covered throughout with a thin layer of the tissue of the Stromatoporoid, so that it is never possible in thin sections to find any portions of the walls of the "Caunopora-tubes" which are not covered externally by the ordinary tissue of the Stromatoporoid. The proper wall of the tubes may be quite thin, and may be merely represented by a dark line; but usually the wall is further thickened by an extensive deposit of light-coloured sclerenchyma by which the internal cavity of the tube is much contracted (Plate X, fig. 11). In some thin sections I have been unable to make out any proper wall

to the "Caunopora-tubes," the walls of which appear to be composed only of the ordinary tissue of the Stromatoporoid-colony. Little stress, however, can be laid upon this observation, as it might merely be a case in which the original walls of the "Caunopora-tubes" had been gradually absorbed and "replaced" by the Stromatoporoid, after the fashion so well known in the recent *Hydractinia.*

3. It has hitherto proved impossible to demonstrate in a satisfactory way the existence of any communication between the cavities of the "Caunopora-tubes" and the interlaminar spaces or zoöidal tubes of the investing Stromatoporoid. Some thin sections appear to show the occasional existence of such a communication; others show no traces of anything of the kind. In the absence of any clear and positive proof of the existence of such a communication we are precluded from any comparison between the "tubes" of "*Caunopora*" and the gastropores of the *Milleporidæ* and *Stylasteridæ.* The absence, therefore, of a proved cœnosarcal connection between the "Caunopora-tubes" and the investing Stromatoporoid is in my opinion the strongest of all arguments in favour of the theory of commensalism—in spite of the great difficulties which this theory has to overcome. Indeed, till such a connection can be shown to exist—and I am not prepared to assert positively that it may not yet be shown to exist—it does not seem to me possible to definitely accept *any* theory which would regard the "Caunopora-tubes" as constitutent parts of the organisms in which they are found.

4. Most well-preserved specimens of "*Caunopora*" and "*Diapora,*" when examined in thin sections, can be shown to have their tubes intersected by a larger or smaller number of "*tabulæ,*" which are sometimes flat or simply curved, sometimes vesicular, and often infundibuliform. Very commonly the same tube will be provided in part with flat tabulæ, and in part with vesicular or funnel-shaped tabulæ (Plate X, figs. 1 and 2). I entertain little doubt but that the tubes of "*Caunopora*" and "*Diapora*" really always possess these tabulæ; though owing to imperfect preservation (as, for example, in most of the Devonshire specimens) their presence may be difficult to demonstrate or they cannot be shown to exist at all. Owing to the presence of these tabulæ, longitudinal and transverse sections of the tubes of "*Caunopora*" and "*Diapora*" possess a striking resemblance to corresponding sections of the corallum of *Syringopora,* or, to a less degree, of *Aulopora.* It appears to me, however, that it is easy to give a far more than due weight to this resemblance, since precisely similar "tabulæ," exhibiting precisely similar variations in their form and arrangement, can be shown to exist in the astrorhizal canals of certain *Stromatoporellæ* and in the axial canals of *Idiostroma, Stachyodes,* and *Amphipora;* and it cannot be doubted that *these* tubes belong to the Stromatoporoid in which they are found.

5. A much more weighty argument in favour of the theory of commensalism may be based upon the discovery, which I have recently made, that the "tubes"

of certain "*Caunoporæ*" and "*Diaporæ*" are provided with *septal spines*. I have already described and figured these structures (Fig. 17), and need only repeat here that in their structure and general arrangement they show nothing which would distinguish them from the corresponding septal spines of a *Syringopora* or a *Favosites*. The only existing *Hydrozoa* which have any structures which could be confounded with the "septa" of the *Actinozoa* are the Stylasterids, in some of which the dactylopores of each cyclo-system are separated by thin radiating partitions or "pseudo-septa" (Moseley). These structures, however, have no resemblance to the rows of septal spinules just alluded to as occurring in the interior of the tubes of certain of the "*Caunoporæ*" and "*Diaporæ*." It appears, therefore, to be quite certain that in all those "*Caunoporæ*" and "*Diaporæ*" in which the tubes possess septal spines, the tubes must be foreign to the Stromatoporoid in which they are found, and must belong to some *Actinozoön*. Moreover, as those "*Caunoporæ*" and "*Diaporæ*" in which the tubes have septal spines are in no other respect distinguishable from those in which the tubes appear to be without such spines, it seems hardly possible to evade the conclusion that in the latter also the "tubes" are foreign structures.

(c) *Syringopora as the Commensal of Caunopora.*—Admitting that the so-called "*Caunoporæ*" and "*Diaporæ*" are the result of the commensalism of some Coral and some Stromatoporoid, the nature of the Corals concerned in the process still remains for determination. The settlement of this point has proved a matter of extreme difficulty, since the choice seems in most cases to lie between *Syringopora* and *Aulopora*, and neither of these genera fulfils all the requirements of the case.

If we take the larger and more massive examples of "*Caunopora*," and imagine the investing Stromatoporoid to be removed, there is no doubt but that the aggregate of the embedded tubes would show a close *general* resemblance to the corallum of *Syringopora*. In such examples the "Caunopora-tubes" are very long, run parallel with one another, and are connected by cross-branches which sometimes give origin to new vertical tubes instead of opening into an adjoining tube. In their internal structure, also, the tubes would answer very well for *Syringopora*-tubes. The tabulæ of *Syringopora*, though usually funnel-shaped, are sometimes simply flat or curved (*e. g.* in *S. geniculata*, Phill.), and sections of the "Caunopora-tubes" show all the phenomena which are seen in similar sections of *Syringopora*, as regards the "tabulæ." The septal spines of the "Caunopora-tubes" are likewise—when present—quite like those of *Syringopora*, except that there appear to be only eight rows of these structures in each tube, whereas there are generally from twelve to twenty of such rows in *Syringopora*.

There are, however, in spite of these resemblances, great difficulties in the way of supposing that the "Caunopora-tubes" are really referable to *Syringopora*. In the first place, very many "*Caunoporæ*" and most "*Diaporæ*" are not massive,

but form thin, laminar expansions, often of great size, the thickness of which varies from 4—6 mm. up to perhaps 2—4 cm. In such cases, the embedded tubes, if set free from their investment, would be quite unlike any known *Syringopora*, and would much more closely approach the general characters of an *Aulopora*-colony. In the second place, there are no known species of *Syringopora* which possess such exceedingly delicate tubes as those of many "*Caunoporæ*" and "*Diaporæ*." In many examples of the latter I find the tubes to be not more than perhaps $\frac{1}{3}$ mm. in diameter, and they are sometimes even smaller than this (Plate XI, fig. 17). As regards the Devonian species of *Syringopora*, Schlüter ('Sitzungsberichte der niederrhein. Gesell.,' 1885) states that his *S. tenuis* has the smallest tubes of any species of *Syringopora* known to occur in the Middle Devonian of the Rhenish region, in which "*Caunoporæ*" are very abundant. The diameter of the corallites in this species are stated not to exceed 1 mm.; and in the *Syringopora moravica* of Ferd. Roemer ('Leth. Pal.,' p. 495), from the Devonian of Olmütz, the corallites are said to be only $\frac{2}{3}$ mm. in diameter. In both of these, however, the diameter of the corallites much exceeds that of the tubes of many "*Caunoporæ*," and the tubes in most species of *Syringopora* are much larger than in these two.

In the third place, the massive examples of "*Caunopora*," which otherwise most resemble *Syringoporæ*, have the tubes much more regularly spaced, and much more uniformly parallel, than we see them to be in any known species of the genus *Syringopora*. In many specimens in which the entire colony may be some inches in thickness, the mass is traversed throughout by straight parallel tubes which may be from $\frac{1}{3}$ to $\frac{1}{2}$ mm. in diameter, and which on an average are placed at about a millimetre apart. On the other hand, in all the known *Syringoporæ* the tubes are not only thicker, but much more irregular in their growth, being invariably more or less flexuous, and thus more or less intertwined with one another.

Again, we have not at present any right to assume that septal spines are always present in the tubes of "*Caunopora*." The discovery of these structures in certain "*Caunoporæ*" and "*Diaporæ*" has certainly greatly lessened the difficulty of accepting *Syringopora* as the "commensal" of these fossils, but many excellently preserved specimens show no traces of these structures, and they do not seem therefore to have been uniformly present. On the other hand, all the *Syringoporæ* appear to possess septal spines in the corallites.

Lastly, there are formations or localities in which "*Caunoporæ*" and "*Diaporæ*" are very abundant, but in which no examples of *Syringopora* have ever been detected. Thus at Büchel in the Paffrath district, we find an enormous number of "*Caunoporæ*" and "*Diaporæ*," but no single example of a *Syringopora* has ever been found, though *Aulopora*-colonies are sufficiently abundant. This is true also, so far as I am aware, of another well-known German locality, viz. Gerolstein in the Eifel. It is also true, in a general way at any rate, of the Devonian Lime-

stones of Devonshire, in which "*Caunoporæ*" are extremely abundant, while *Syringoporæ* are nearly unknown. Of course, in such cases it might be said that the reason of the absence or scarcity of *Syringoporæ* is merely that these Corals have wholly or mostly become commensals with Stromatoporoids, and have thus become "*Caunoporæ*;" but till it is proved that the "*Caunopora*-tubes" belong to *Syringopora*, this seems to me to be to some extent begging the question at issue.

It seems, at any rate, certain that if we accept *Syringopora* as the Coral which is concerned in the production of "*Caunoporæ*" and "*Diaporæ*" we must at the same time make two admissions which are attended with more or less of doubt and difficulty. In the first place, we must admit that the *Syringoporæ*, when growing commensally with Stromatoporoids, to some extent alter their normal mode of growth, in so far as to grow with much greater regularity and uniformity than they do in their free state. This admission is not of much importance, because we must make the same, on a considerably larger scale, if we suppose *Aulopora* to be the Coral concerned in the production of "*Caunoporæ*" and "*Diaporæ*." A much more important admission is that we are compelled to suppose that many of the *Syringoporæ* which give rise to "*Caunoporæ*" belong to species which are unknown in their free state, and which never occur except when thus living commensally with some Stromatoporoid; since no known species of this genus of Corals has tubes nearly so minute as those of certain "*Caunoporæ*." The difficulties connected with this admission are so great that at present I do not see how it is possible to accept *Syringopora* as being the genus of Corals *usually* concerned in the production of "*Caunopora*"-colonies.

(D) *Aulopora as the Commensal of Caunopora.*—As previously stated, Roemer ultimately came to the conclusion that *Aulopora*, and not *Syringopora*, was the Coral concerned in the production of "*Caunoporæ*." If we take the thin laminar expansions of the "*Diaporæ*" and of some "*Caunoporæ*" then there is no doubt that the embedded tubes, if divested of the enveloping Stromatoporoid, would much more nearly resemble an *Aulopora*-colony than a *Syringopora*. In some very thin specimens, the embedded tubes consist of nothing except an irregular series of horizontal stolons, sending out short erect branches, which do not seem to be connected by cross-tubes. In most specimens, however, the tubes grow vertically upwards to the full thickness of the cœnosteum, and are connected by cross-tubes at varying heights, thus losing their general resemblance to *Auloporæ*. Even in the thicker examples of the laminar "*Caunoporæ*" and "*Diaporæ*," it is, however, not unusual to find that horizontal stolons are developed at more than one level in the fossil, showing that different sets of the "*Caunopora*-tubes" succeeded each other vertically at intervals of time. As a general rule, however, the tubes are continuous in the particular types here alluded to.

The tabulæ of the "*Caunopora*-tubes," though more like those of *Syringopora*

than those usual in *Aulopora*, would nevertheless answer sufficiently well to the tabulæ seen in species of the latter genus. Many *Auloporæ*, in fact, have a mixture of curved or straight tabulæ with vesicular or funnel-shaped tabulæ, such as occur so commonly in "*Caunopora*-tubes."

Moreover, when we meet, in a single locality, with examples of "*Caunopora*" and "*Diapora*," which differ from one another in the sizes of the embedded tubes, irrespective of the nature of the "ground-mass," then it is not unusual to find *free* colonies of different species of *Aulopora*, differing from one another in having differently-sized tubes, in the same locality.

One great argument, however, against accepting *Aulopora* as the commensal of "*Caunopora*" and "*Diapora*" is that though *Auloporæ* with differently-sized tubes occur in strata where the latter fossils also have tubes of different sizes, there are no known species of *Aulopora* in the Devonian Rocks which have tubes so small as those of certain *Caunoporæ* (viz. about $\frac{1}{3}$ mm. in diameter). In the case of such types, therefore, we have the same difficulty in taking *Aulopora* as the commensal of "*Caunopora*" that I have shown to exist in the case of *Syringopora*. We should have, namely, to suppose that certain of the *Auloporæ* concerned in the production of "*Caunoporæ*" and "*Diaporæ*" are types not known to exist in the free condition.

The corallites of *Aulopora* are also not known to possess any septal spines, whereas certain "*Caunopora*-tubes" undoubtedly possess these structures. Again, free colonies of *Aulopora* (*i. e.* colonies merely attached by their lower surface) do not send up straight vertical tubes such as are seen in "*Caunopora*" and "*Diapora*;" nor do the tubes, once produced, become connected by horizontal tubes or cross-branches. Lastly, colonies of *Aulopora* are very abundant in both Silurian and Devonian strata, growing on the upper or under surface of Stromatoporoids, but *not* giving rise to "*Caunoporæ*" or "*Diaporæ*."

The difficulties which attend the hypothesis that the "tubes" of even the laminar forms of "*Caunopora*" and "*Diapora*" are referable to *Aulopora*, are well exemplified by such a type as *Stromatoporella* (*Diapora*) *laminata*, Barg., which occurs in great numbers and in wonderful preservation (showing both its upper and lower surfaces in perfection) in the quarry of Büchel, in the Devonian Limestones of the Paffrath district. This interesting type forms laminar expansions, often of great size, and completely covered below with a striated epitheca, being only very rarely incrusting. The cœnosteum varies in thickness from 2—3 mm. up to 2—3 cm., according to the age of the colony. Whatever the thickness may be, the under surface shows no signs of the tubes, whereas the upper surface shows the circular apertures of the tubes distributed uniformly and at tolerably regular intervals, and having their margins just level with the last-formed layer of the Stromatoporoid (Plate X, fig. 3). Vertical sections further would show that, whether the

cœnosteum be thin or thick, the tubes arise from a level a little above the epitheca, and are continued in an essentially vertical course through the whole thickness of the Stromatoporoid to terminate above in the rounded apertures on the surface. Now, it is quite clear that in this case the epitheca and the first layer of the Stromatoporoid must have existed before the "*Diapora*" tubes were produced. On the theory of commensalism, therefore, we must imagine that the Stromatoporoid after forming its original epitheca, and one or more of its first laminæ, became covered by an *Aulopora*-colony. This latter must have covered the greater part, at any rate, of the upper surface of the Stromatoporoid, and must have produced its first set of tubes with great regularity. Then, as the Stromatoporoid continued its growth by the upward extension of its pillars and by the formation of fresh laminæ, the *Aulopora* must have lengthened its tubes to a corresponding extent, the tubes growing up in a vertical direction, and always keeping pace with the Stromatoporoid, in such a way that the mouths of the tubes were always just flush with the last-formed layer of the Stromatoporoid. Moreover, every now and then horizontal stolons would be thrown out from the lips of the tubes and would become connected with the lips of neighbouring tubes. If, therefore, we removed the enveloping Stromatoporoid, and could examine the embedded tubes alone, we should find a creeping and very regularly-developed network of horizontal tubes, which at tolerably regular intervals would throw up straight vertical tubes, which would be tolerably equal in length and would be joined at different levels by a variable number of horizontal connecting-tubes. The appearances just described differ, however, to a serious extent, from anything that we know of in any species of *Aulopora* when having its normal mode of growth, and when it is attached parasitically to the exterior of any foreign organism such as a Stromatoporoid or a Coral. Under ordinary conditions, namely, an *Aulopora*-colony has a very irregular mode of growth, generally forming loose straggling networks, which throw up tubes at irregular intervals. Furthermore, the calices in such a colony are reclined; they do not show any tendency to grow up vertically; and though they may throw out creeping stolons which in turn become calices, they do not become united with one another by a system of horizontal connecting-processes.

The above-mentioned differences between an ordinary *Aulopora*-colony and the aggregate of tubes of a "*Caunopora*" or "*Diapora*" are so striking that we cannot apparently accept of *Aulopora* as being the Coral which gives rise to these latter fossils, except upon the hypothesis that when living as a commensal with certain types of Stromatoporoids, the *Aulopora* is forced to completely alter its normal mode of growth. The change in its environment caused by the commensalism must be supposed to induce the *Aulopora* to enter upon a more active and vigorous as well as a much modified mode of increase. It must be supposed to throw out

tubes at much more regular and less distant intervals than it would normally do; and at the same time to abandon its natural *creeping* habit, and to send up vertical tubes which continue their growth upwards to an apparently almost indefinite extent. Moreover, instead of producing horizontal stolons at a single level only, namely, in the plane of the general creeping expansion, it must be supposed to go on producing horizontal processes or connecting-tubes at successive levels in the mass. It is, in fact, not uncommon in some types, such as *Stromatoporella* (*Diapora*) *laminata*, Barg., to find such horizontal stolons developed on the upper surface of the last-formed layer of the Stromatoporoid (Pl. X, fig. 3), in which cases the appearances produced often closely resemble those presented by an ordinary *Aulopora*-colony. Professor Ferdinand Roemer has explained the apparent continued growth upwards of the "*Caunopora*-tubes" as being perhaps due to the fact that a single "*Caunopora*" may be the result of the combined growth of one Stromatoporoid with many successive colonies of *Aulopora*. I am, however, satisfied that, in the case of most laminar examples of "*Caunopora*" at any rate, only *one Aulopora*-colony is concerned, and that the tubes which arise from the basal reticulation are continued upwards through the mass to the upper surface. I believe that this is also commonly the case in the massive examples of "*Caunopora*," though in the case of these it is difficult to prove this positively.

There are, no doubt, great difficulties in the way of accepting the view that *Auloporæ* when living commensally with Stromatoporoids so fundamentally change their natural mode of growth, as they must be supposed to do if we are to regard them as giving rise to "*Caunoporæ*" and "*Diaporæ*." Upon the whole, however, I think the difficulties in the way of this hypothesis are not so great as those are which confront us if we select *Syringopora* as the commensal of "*Caunopora*." Possibly some of these difficulties might be evaded by supposing that in some "*Caunoporæ*" and "*Diaporæ*" the tubes belong to *Aulopora*, while in others they belong to *Syringopora*. If we retain the theory of the commensalism of "*Caunopora*," but do not accept either *Aulopora* or *Syringopora* as the source of the "tubes," we are driven to the exceedingly improbable hypothesis that these structures belong to a genus of Corals, the species of which are totally unknown, save when living as commensals with certain Stromatoporoids.

I may just add here that I have found a single example of a "*Diapora*" from the Devonian Rocks of Devonshire in which the tubes resemble neither *Syringopora* nor *Aulopora*, but are more like those of the Auloporoid genus *Romingeria*, Nich. In this singular specimen, the tubes are aggregated into cylindrical bundles, which would closely resemble the stems of a slender *Pachypora*, except that they give out at intervals *detached* tubes which radiate outwards to a considerable distance from the central bundle of tubes. I shall describe and figure this specimen later on, and need not say more about it at this moment.

III. *Caunopora and Diapora as "states" of Stromatopora and Stromatoporella.*

The only other hypothesis which seems worth a moment's consideration as an alternative to the theory of commensalism, is that the ordinary "*Caunoporæ*" and "*Diaporæ*" are *states* of certain species of *Stromatopora* and *Stromatoporella.* The fact that the "*Caunopora*-tubes" are, as a rule, only found in particular species, belonging to particular genera, affords *primâ facie* ground for supposing that they belong to the species in which they are found. We have seen, however, that all the species which exhibit these tubes also exist without the tubes. It is therefore clear that if the "*Caunopora*-tubes" belong to the organism with which they are associated, they can only represent structures which are developed in certain individuals and not in others. It would therefore be a not unnatural hypothesis to suppose that the "tubes" of "*Caunopora*" and "*Diapora*" represent the cavities in which the reproductive zoöids were lodged. I was at one time strongly tempted to take this view, and there are certain facts which would go a considerable way in its support. Thus, there is an undoubted resemblance between the "*Caunopora*-tubes" and the tabulate axial tubes of *Idiostroma, Stachyodes*, and *Amphipora,* these structures belonging unquestionably to the organism in which they are found. Again, there is a still more striking resemblance between the tubes of "*Caunopora*" and "*Diapora*" on the one hand and the large round-mouthed tubes of *Idiostroma oculatum*, Nich., on the other hand. These resemblances do not, however, go far enough. Thus, the tabulate axial tubes of *Idiostroma* and its allies have no proper walls, and communicate freely with the cœnosarcal canals of the general skeleton. In *Idiostroma oculatum*, also, the large round-mouthed and tabulate tubes, though furnished with proper walls near their mouths, appear to lose these walls internally, and also seem to communicate freely at their bases with the interlaminar spaces of the general skeleton. Until, however, we obtain something like positive proof of the existence of a free communication between the cavities of the tubes of "*Caunopora*" and "*Diapora*" on the one hand and the cœnosarcal canals of the surrounding Stromatoporoid on the other hand, it seems impossible to accept any hypothesis which would treat these tubes as being constituent parts of the Stromatoporoid in which they are found. Moreover, it is now certain that "*Caunoporæ*" and "*Diaporæ*" are not *exclusively* referable, as regards the tissue of the enveloping Stromatoporoid, to the two genera *Stromatopora* and *Stromatoporella.* Had this held good, there would have been strong ground for regarding the embedded "*Caunopora*-tubes" as belonging to the investing Stromatoporoid. We now know, however, that species of other genera than the two first mentioned occur occasionally as "*Caunoporæ.*" Upon the whole,

therefore, I think we must at present conclude that the fossils ordinarily called "*Caunoporæ*" and "*Diaporæ*" are the result of the combined growth of some Stromatoporoid with some Coral, the former usually being a species of *Stromatopora* or *Stromatoporella,* and the latter generally belonging either to *Syringopora* or to *Aulopora.* We must also conclude, however, that there are other fossils, in general aspect exceedingly similar to the ordinary "*Caunoporæ*," in which the embedded tubes really do belong to the organism in which they are found; as we have seen to be the case in *Idiostroma oculatum.* In practice, therefore, each individual specimen must, with our present knowledge, be judged on its own merits, apart from all preconceived theories. Moreover, as the "*Caunoporæ*" and "*Diaporæ*" show many points of interest which are quite independent of any hypothesis as to their actual nature, I shall, where needful, describe and figure any noticeable features in connection with the "Caunopora-state" of certain Stromatoporoids, irrespective of all theoretical views as to the precise nature of this "state."

PLATE I.

[*Unless otherwise stated, all the specimens figured are in the collection of the Author.*]

Fig. 1.—*Clathrodictyon striatellum*, d'Orb.; vertical section, enlarged 24 times, showing the granular aspect of the skeleton-fibre, with indications of a median dark line in the horizontal laminæ. Wenlock Limestone, Ironbridge.

Fig. 2.—*Clathrodictyon cellulosum*, Nich. and Mur.; vertical section, enlarged 24 times. The specimen is silicified, and the cavities of the skeleton have first been lined with a layer of minute crystals, and subsequently filled with transparent silica, often containing orbicular masses. The skeleton-fibre is traversed by minute transverse lines of a lighter colour than the rest of the fibre, probably representing minute canals. Corniferous Limestone, Ontario.

Fig. 3.—*Stromatopora typica*, Rosen; tangential section, enlarged 24 times, showing the minutely porous character of the skeleton-fibre. Wenlock Limestone, Ironbridge.

Fig. 4.—*Stromatoporella granulata*, Nich.; tangential section, enlarged 48 times, showing the minute pores and channels in the skeleton-fibre. Hamilton Formation, Arkona, Ontario.

Fig. 5.—Vertical section of the same, similarly enlarged, showing the minute tubular spaces and the clear median line in the skeleton-fibre.

Fig. 6.—*Stromatopora Carteri*, n. sp.; tangential section, enlarged 48 times, showing the porous skeleton-fibre. Wenlock Limestone, Ironbridge.

Fig. 7.—Vertical section of the same, similarly enlarged. *t t*, zoöidal tubes.

Fig. 8.—*Actinostroma clathratum*, Nich.; tangential section, enlarged 12 times, showing the cut ends of the radial pillars. The section passes for the most part along the plane of a horizontal lamina. Devonian, Dartington, South Devon.

Fig. 9.—Vertical section of the same, similarly enlarged, showing the "continuous" radial pillars.

Fig. 10.—Part of tangential section of the same, enlarged 48 times, showing the presence of an axial canal in some of the radial pillars.

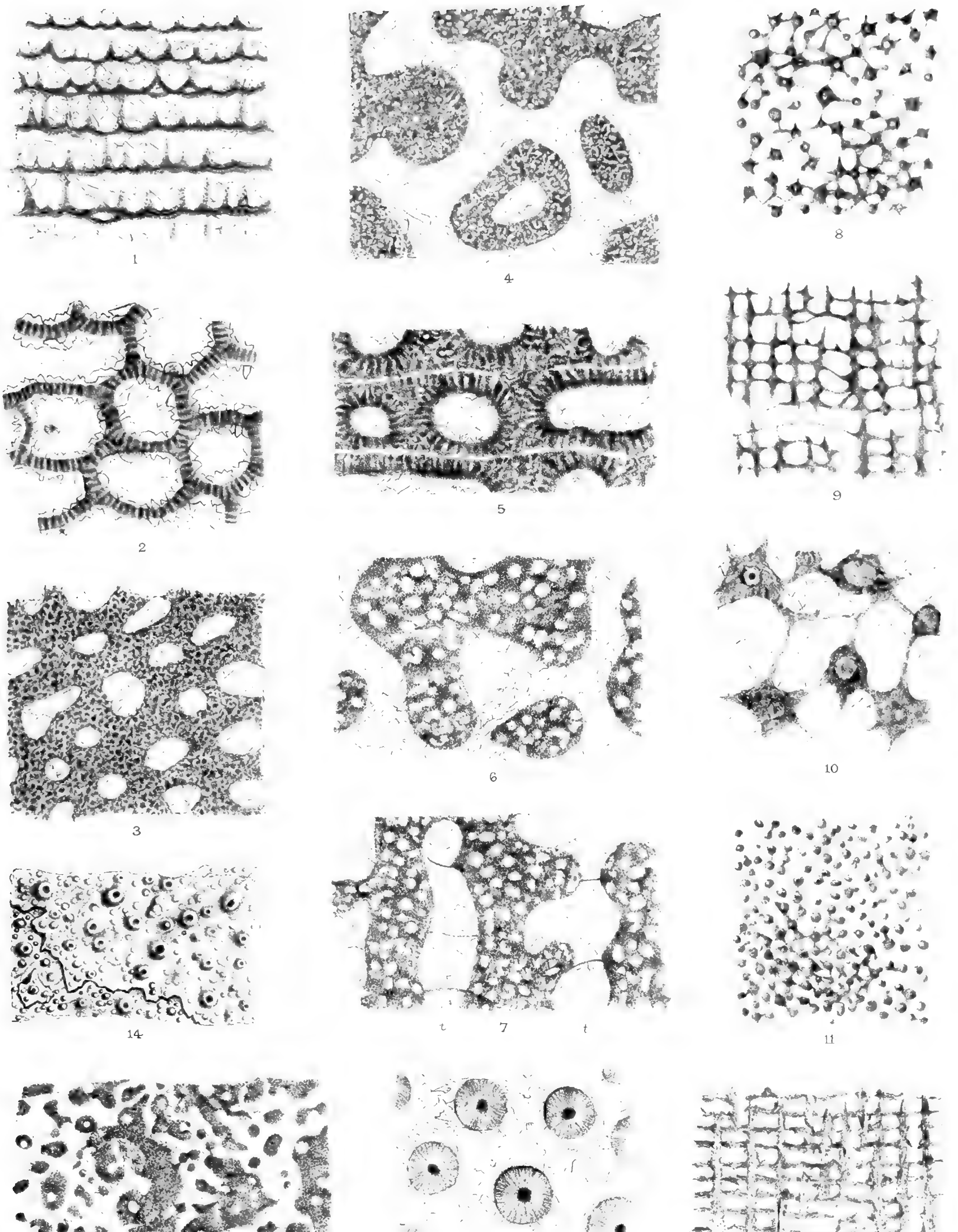
Fig. 11.—*Actinostroma clathratum*, Nich.; tangential section, enlarged 12 times. The section passes partly along the plane of one of the laminæ, and partly through one of the interlaminar spaces. Middle Devonian, Gerolstein.

Fig. 12.—Vertical section of the same, similarly enlarged.

Fig. 13.—Part of tangential section of the same, enlarged 48 times, passing along an interlaminar space, and showing the axial canals in the radial pillars.

Fig. 14.—*Stromatoporella granulata*, Nich.; surface magnified, and showing the openings of the zoöidal tubes on large round tubercles, the radial pillars terminating in blunt imperforate tubercles. Corniferous Limestone, Ontario.

Fig. 15.—*Stromatoporella granulata*, Nich.; tangential section, enlarged 12 times, showing the transversely-divided, irregular zoöidal tubes (*t*). Hamilton Formation, Arkona, Ontario.



H. A. Nicholson del.
A. T. Hollick. lith.

West, Newman & Co imp.

PLATE II.

Fig. 1.—*Labechia ohioensis*, n. sp.; vertical section, enlarged 12 times. Cincinnati group, Waynesville, Ohio.

Fig. 2.—Tangential section, similarly enlarged. In this specimen the cavities of the skeleton have been filled with opaque calcareous mud, and the skeleton has been subsequently dissolved out, and replaced by transparent calcite.

Fig. 3.—*Labechia canadensis*, Nich. and Mur. sp.; vertical section enlarged $2\frac{1}{2}$ times. Trenton Limestone, Peterboro', Ontario. The skeleton has been "replaced" by calcite, so that the rows of dark oblong masses represent the dense matrix filling the chambers, and the clear spaces of the drawing represent the original skeletal framework.

Fig. 4.—Another vertical section of the same, enlarged 12 times.

Fig. 5.—The same drawn as if it had been preserved in the usual way, *i. e.* having the chambers of the cœnosteum filled with transparent calcite, and the skeletal framework opaque.

Fig. 6.—*Parallelopora ostiolata*, Barg.; tangential section, enlarged 48 times. Devonian, Büchel (Paffrath district).

Fig. 7.—Vertical section of the same, similarly enlarged. The sections show the reticulate skeleton-fibre, traversed by numerous minute, dark, rod-like bodies, which appear to be really tubuli injected with some opaque material. *t t*, tabulate zoöidal tubes.

Fig. 8.—*Clathrodictyon regulare*, Rosen; vertical section, enlarged 24 times. The concentric laminæ show a delicate median line. Wenlock Limestone, Dudley.

Fig. 9.—*Stromatoporella eifeliensis*, Nich. (?); tangential section, enlarged 12 times, showing the irregular zoöidal tubes (*t t*) transversely divided. Devonian, Teignmouth.

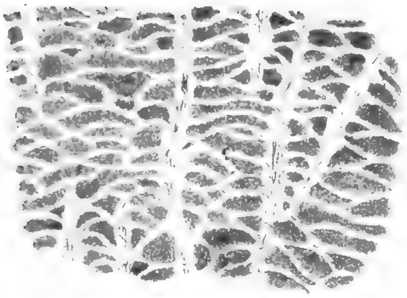
Fig. 10.—Vertical section of the same, similarly enlarged. The irregular zoöidal tubes are here seen to be crossed by tabulæ, and to extend from one interlaminar space to the next above, or to the one above that.

Fig. 11.—*Actinostroma clathratum*, Nich.; surface enlarged about 12 times. Devonian, Hebborn (Paffrath district).

Fig. 12.—*Clathrodictyon regulare*, Rosen; surface enlarged about 12 times. Wenlock Limestone, Dudley.

Fig. 13.—*Clathrodictyon fastigiatum*, n. sp.; surface enlarged about 12 times. Wenlock Limestone, Dormington.

Fig. 14.—*Stromatoporella* sp. (? *S. curiosa*, Barg.). A broken fragment of the natural size, having the surface covered with a smooth and apparently imperforate calcareous membrane. Middle Devonian, Büchel (Paffrath district).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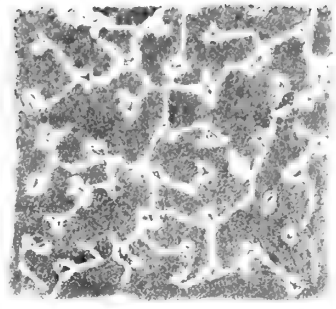
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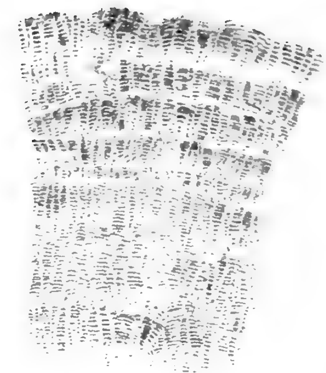
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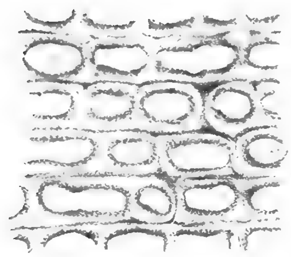
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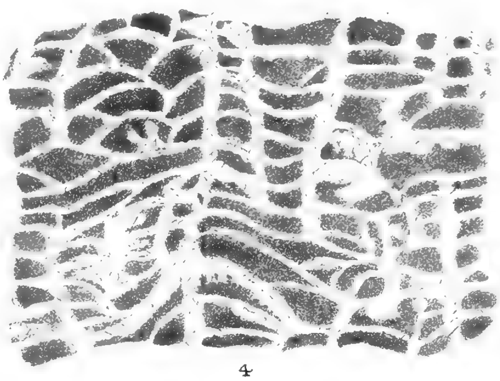
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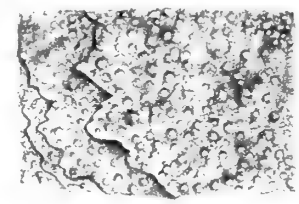
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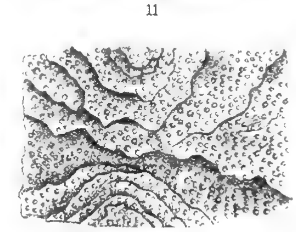
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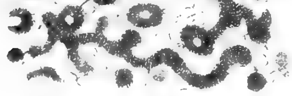
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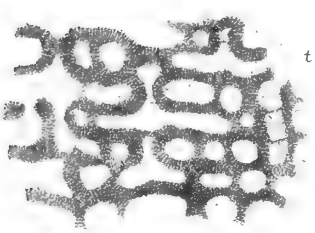

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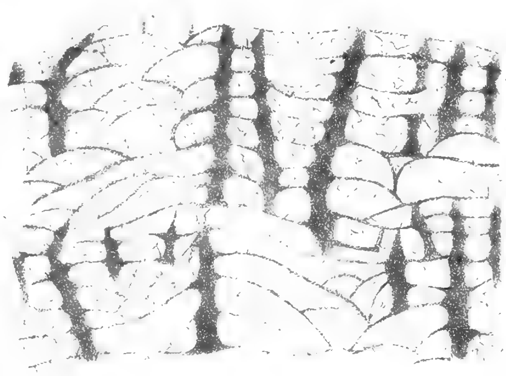
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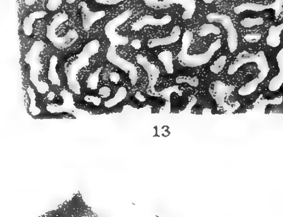
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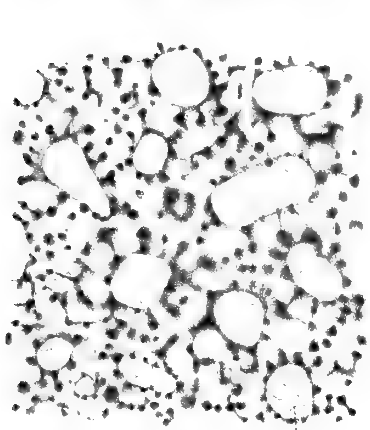
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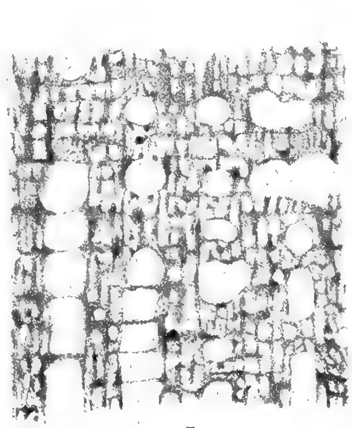
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H. A Nicholson del.
A. T. Hollick lith

West Newman & Co imp

PLATE III.

Fig. 1.—*Hermatostroma Schlüteri*, n. sp.; tangential section enlarged 12 times. Devonian, Hebborn (Paffrath district).

Fig. 2.—Vertical section of the same, similarly enlarged. In both these sections we see the wide axial canals of the radial pillars, and the extensions of these canals into the horizontal connecting-processes by which the concentric laminæ are constituted. The entire canal-system is injected with some opaque material, probably oxide of iron.

Fig. 3.—One of the astrorhizæ of *Stromatopora discoidea,* Lonsd., enlarged 6 times. Wenlock Limestone, Wisby, Gotland.

Fig. 4.—*Stromatopora* (*Stachyodes?*) *polyostiolata*, Barg., of the natural size. Middle Devonian, Eifel. The specimen shows nipple-shaped prominences, at the summits of which are placed the surface-openings of a system of large canals, which traverse the skeleton at regular intervals, and which represent either the axial tubes of a *Stachyodes* or the central canals of the astrorhizal systems. [This figure is copied from Goldfuss ('Petref. Germ.,' pl. lxiv, fig. 8, *f*), and represents one of the forms which he included under the name of *S. polymorpha.*]

Fig. 5.—*Stromatopora concentrica*, Goldf. var. *colliculata*, Nich. A broken specimen, of the natural size. Middle Devonian, Gerolstein. The prominent monticules on the surface correspond in general with the axes of the astrorhizæ.

Fig. 6.—*Stromatoporella ? incrustans*, Hall and Whitf. sp.; portion of the surface, showing the openings of the astrorhizæ on prominent chimney-like elevations. Devonian Formation, Iowa. [Copied from Hall and Whitfield, 'Twenty-third Ann. Rep. on the State Cabinet,' pl. ix, fig. 3.]

Fig. 7.—*Labechia conferta*, Lonsd.; under side of a large specimen, of the natural size, showing the concentrically-wrinkled epitheca. Wenlock Limestone, Benthall.

Fig. 8.—A small example of *L. conferta,* from the Wenlock Limestone of Gotland, of the natural size.

Fig. 9.—Under surface of a very young example of *L. conferta,* Lonsd. (*Labechia,* n. sp.?), of the natural size. Wenlock Limestone, Dudley.

Fig. 10.—Upper surface of the same, nat. size.

Fig. 11.—Profile of the same.

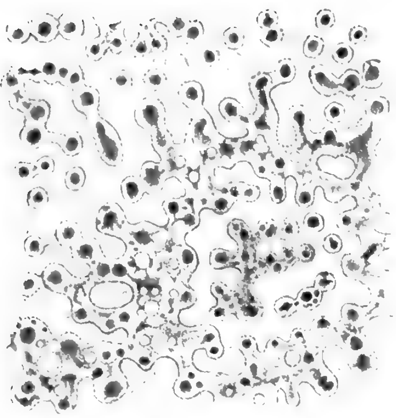
Fig. 12.—Surface of *Labechia conferta,* Lonsd., showing the upward termination of the radial pillars in round tubercles. Enlarged.

Fig. 13.—Surface of another specimen, in which the tubercles are largely confluent. Enlarged.

Fig. 14.—A few tubercles of *L. conferta,* Lonsd., enlarged, showing apparent perforations at their summits.

Fig. 15.—Completely imperforate and confluent tubercle of young *Labechia* (Fig. 9). Enlarged.

PLATE III



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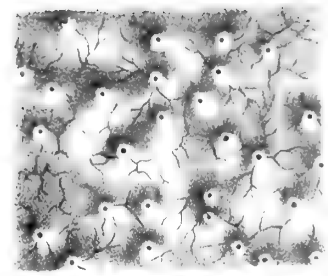

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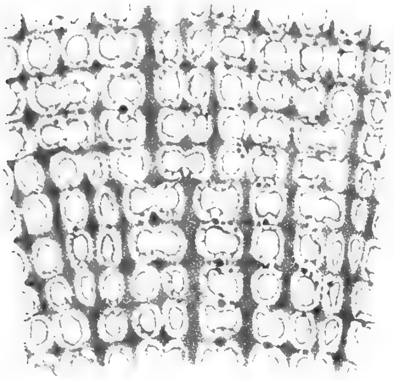

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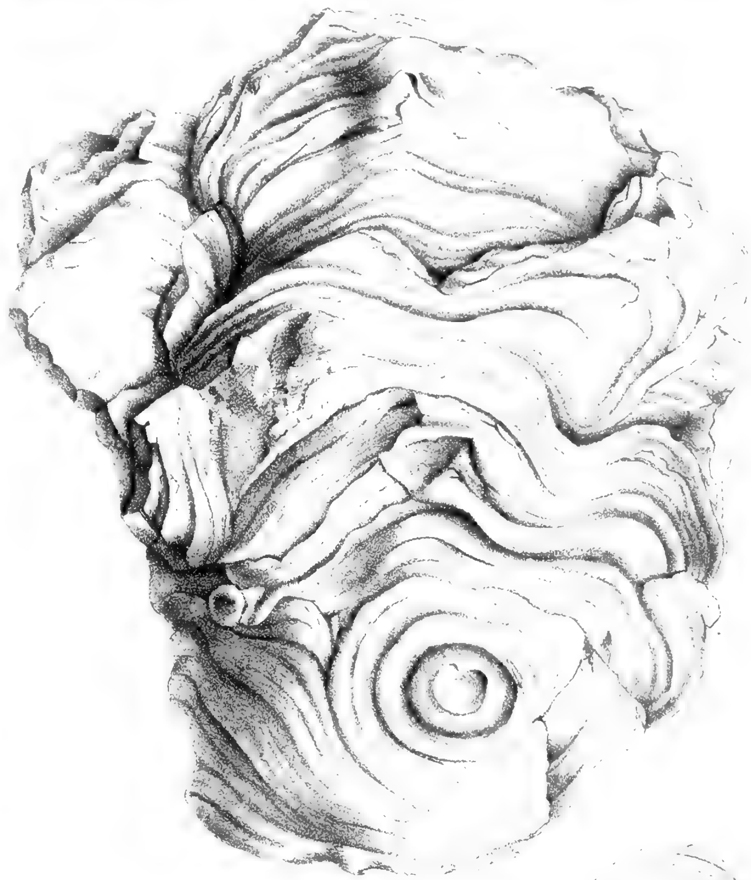

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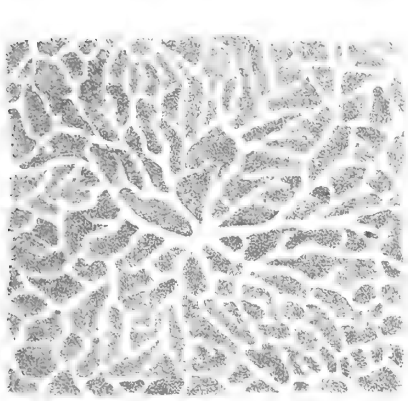

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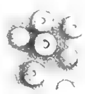

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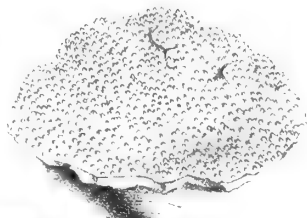

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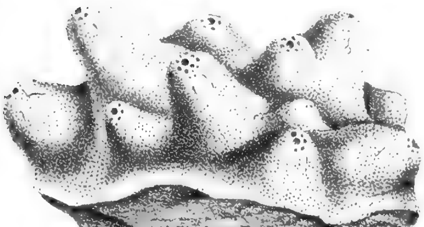

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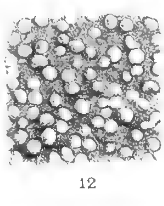

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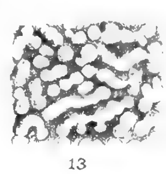

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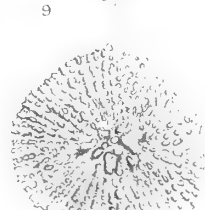

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H. A. Nicholson del.
A. T. Hollick lith.

West Newman & Co imp

PLATE IV.

Fig. 1.—The central portion of the astrorhiza of *Stromatopora ? dartingtonensis*, Cart. (=*Stromatopora elegans*, Carter), enlarged 12 times. Devonian, Teignmouth. The specimen is a "reversed" one, the skeleton being replaced by transparent calcite, and the cavities of the skeleton being opaque.

Fig. 1 *a*.—The same *restored*, showing the skeleton opaque and the canal-system filled with calcite, as is the case in ordinary specimens. [It is to be remembered that the process of replacement, by which such "reversed" specimens as the above are produced, is necessarily an imperfect process. Had the replacing agent been *silica*, instead of *calcite*, the replacement might possibly have been perfect. Hence in such a restoration of a "reversed" specimen as is here attempted, the dark skeletal framework shown in the restoration can only be regarded as giving the *general* form of the skeleton, and not as giving minute structural details.]

Fig. 2.—*Stromatoporella eifeliensis*, n. sp.; portion of the surface of an encrusting specimen, showing the large astrorhizæ, of the natural size. Devonian, Gerolstein.

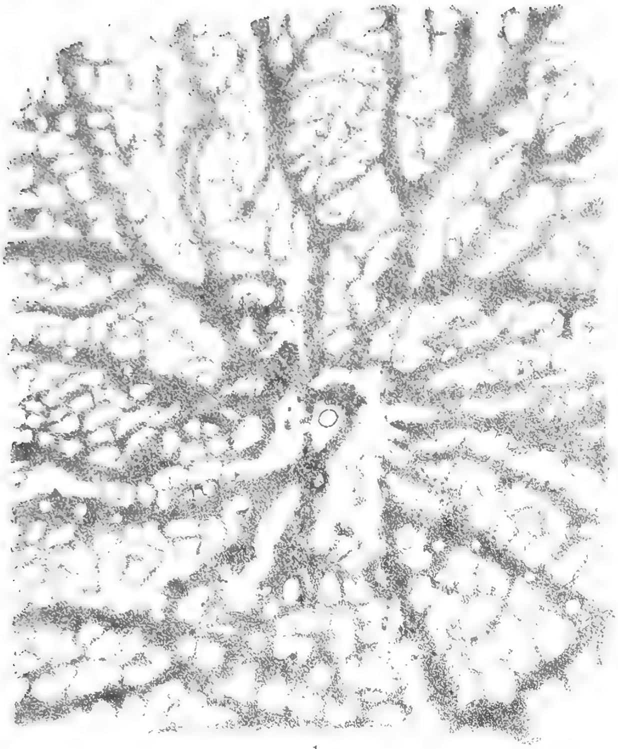
Fig. 3.—*Actinostroma stellulatum*, n. sp.; tangential section, enlarged 12 times, showing one of the astrorhizæ. Devonian, Teignmouth.

Fig. 3 *a*.—Vertical section of another specimen of the same, similarly enlarged. The section traverses one of the wall-less vertical canals connecting successive astrorhizal systems.

Fig. 4.—*Distichopora coccinea*, Gray (recent); tangential section, enlarged 24 times, showing the cœnosarcal canal-system, the gastropores (*g*), and the dactylopores (*d*).

Fig. 5.—Tangential section of the skeleton of a species of *Millepora* (*M. tortuosa*, Dana ?), enlarged 24 times, showing the cœnosarcal canal-system. *g*, One of the gastropores; *d*, one of the dactylopores.

Fig. 6.—*Stromatoporella granulata*, Nich.; part of the surface of a specimen from the Devonian rocks (Hamilton formation), Canada, enlarged about 6 times. The figure shows a conical eminence, upon which opens one of the vertical astrorhizal canals, and from which radiate shallow superficial astrorhizal grooves, formed by lines of elongated or vermiculate tubercles. Some of the larger tubercles show at their summits the apertures of zoöidal tubes; and part of the surface is covered with a smooth calcareous membrane, penetrated by minute isolated circular perforations.



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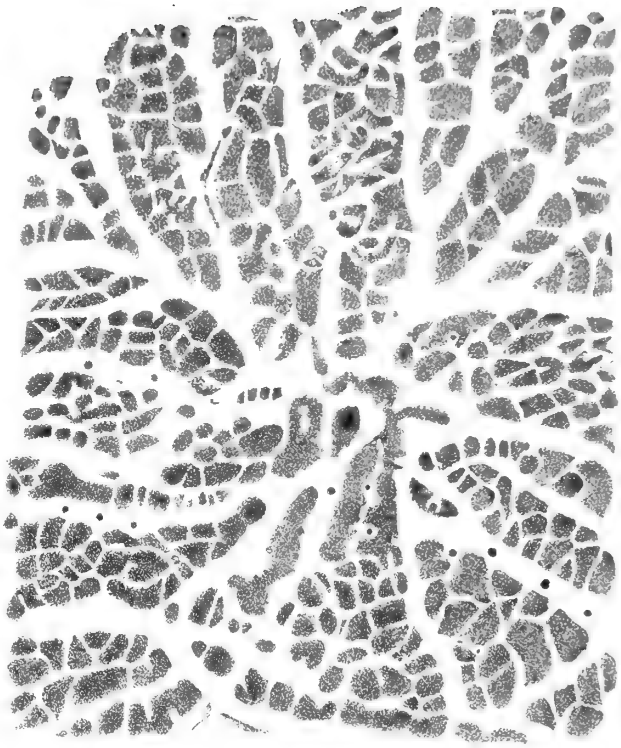

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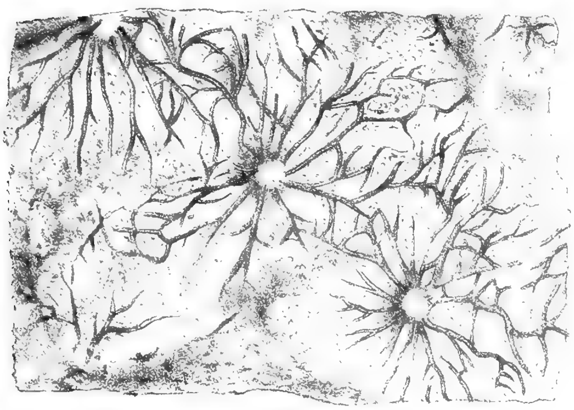

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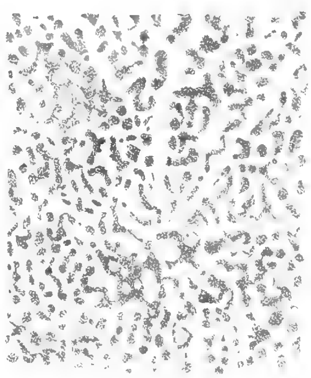

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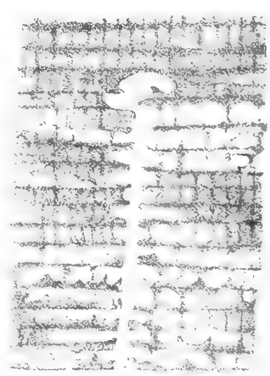

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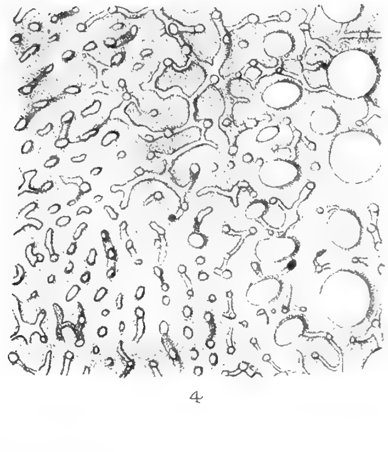

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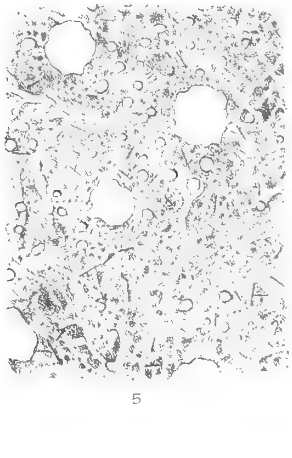

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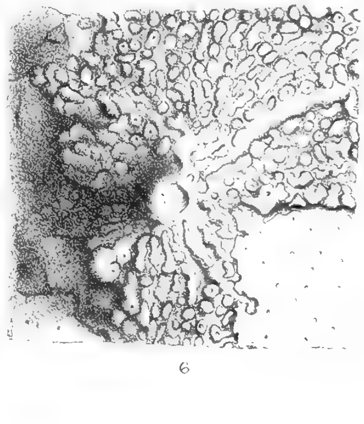

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A. T. Hollick lith

West, Newman & C° imp

PLATE V.

Fig. 1.—*Clathrodictyon regulare*, Rosen; vertical section, enlarged 12 times. Wenlock Limestone, Dudley.

Fig. 2.—Tangential section of the same, similarly enlarged.

Fig. 3.—*Clathrodictyon striatellum*, D'Orb.; vertical section, enlarged 12 times. Wenlock Limestone, Benthall.

Fig. 4. Tangential section of the same, similarly enlarged.

Fig. 5.—*Clathrodictyon vesiculosum*, Nich. and Mur.; vertical section, enlarged 12 times. From the type-specimen of the species, Yellow Springs, Ohio (Clinton Formation).

Fig. 6.—*Clathrodictyon variolare*, Rosen; vertical section, enlarged 12 times. *as*, *as*, cut ends of the astrorhizal canals. Wenlock Limestone, Dormington.

Fig. 7.—Tangential section of the same, similarly enlarged.

Fig. 8.—*Stromatopora antiqua*, Nich. and Mur.; a weathered specimen, of the natural size, showing the "latilaminæ." Niagara Limestone, Thorold, Ontario.

Fig. 9.—Part of a vertical section of the same, enlarged about twice. The "latilaminæ" are only partly in contact, and the spaces between them are filled with the matrix.

Fig. 10.—Vertical section of the same, enlarged 12 times, showing the delicate tabulate zoöidal tubes.

Fig. 11.—Tangential section of the same, enlarged 12 times, showing the cross-sections of the zoöidal tübes as minute apertures in the skeletal framework.

Fig. 12.—*Stromatopora Beuthii*, Barg.; tangential section, enlarged 12 times. The section shows the coarsely-porous skeleton-fibre and the persistence of the radial pillars, the cut ends of which (*p p*) appear immersed in the general reticulation. Devonian, Hebborn (Paffrath district).

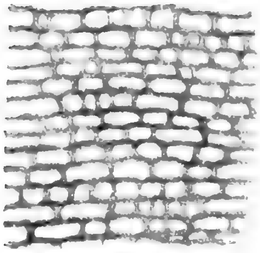
Fig. 13.—Vertical section of the same, similarly enlarged, showing the tabulate zoöidal tubes, and the persistence of the radial pillars (*p p*) in the interior of the skeleton-fibre.

Fig. 14.—*Stromatopora typica*, Rosen; tangential section, enlarged 12 times. The section shows the completely reticulate character of the skeletal tissue and the minutely porous structure of the skeleton-fibre. The apertures in the skeletal network are the cross-sections of the zoöidal tubes. No traces of the radial pillars, as distinct structures, can be detected. Wenlock Limestone, Ironbridge.

Fig. 15.—Vertical section of the same, similarly enlarged. The figure takes in the thickness of a single "latilamina," and shows the tabulate zoöidal tubes.

Fig. 16.—*Stromatopora concentrica*, Goldf., var. *colliculata*, Nich.; tangential section, enlarged 12 times. Middle Devonian, Gerolstein.

Fig. 17.—Vertical section of the same, similarly enlarged. The figure shows that the reticulated skeleton exhibits traces of the concentric laminæ. The section is slightly oblique, and the tabulate zoöidal tubes are, therefore, not well shown.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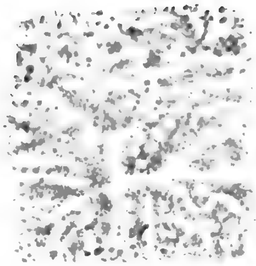
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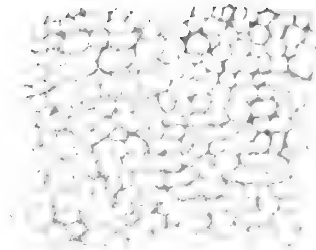
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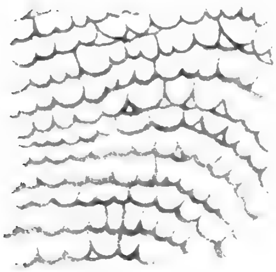
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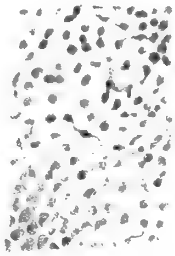
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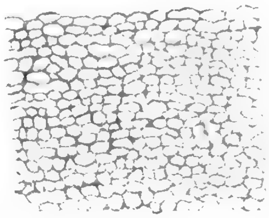
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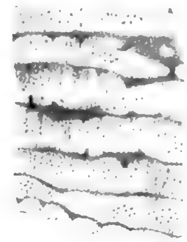
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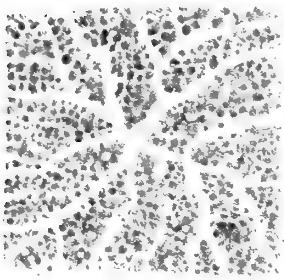
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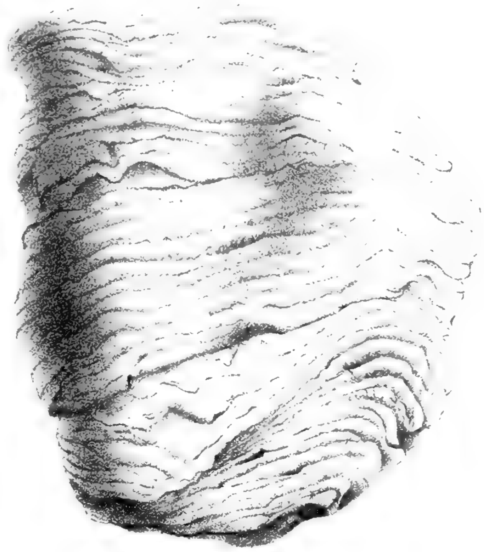
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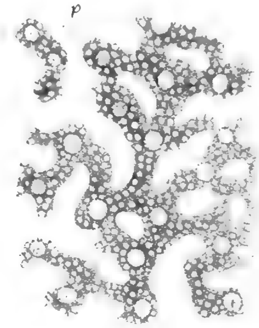
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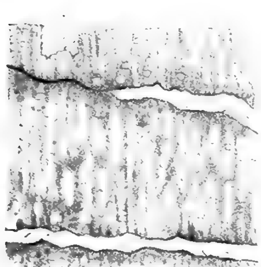
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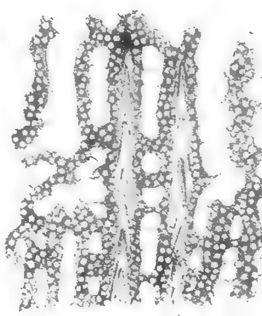
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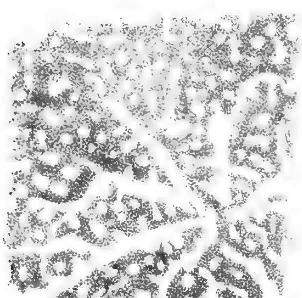
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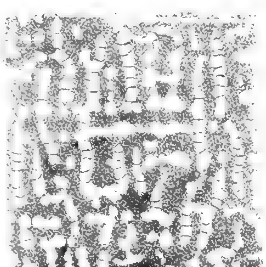
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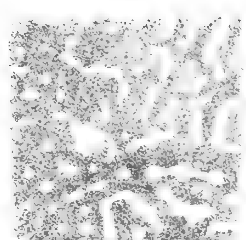
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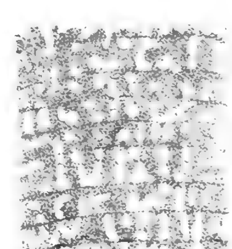
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PLATE VI.

Fig. 1.—*Hydractinia echinata*, Flem. (recent); tangential section of a thick crust, enlarged 90 times. *p p*, Radial pillars, transversely divided. *c c*, Horizontal connecting processes or "arms" given out by the pillars at successive levels.

Fig. 2.—Portion of a young colony of the same, consisting of a single lamina, viewed as a transparent object, and enlarged 90 times. Letters as before.

Fig. 3.—Portion of the surface of *H. echinata*, greatly enlarged. On the left half of the figure the spines (*s*) and the astrorhizal grooves (*g*) are alone shown; while on the right half of the figure are shown the small tubercles (*b*) which represent the free ends of the radial pillars and also the openings of the zoöidal tubes (*t t*).

Fig. 3 *a*.—Part of the surface of the same, free from the large spines, still more highly enlarged. The tubercles representing the free ends of the radial pillars (*p p*) and their horizontal connecting-processes are shown, as well as a few of the openings of the zoöidal tubes.

Fig. 4.—Vertical section of the skeleton of *Hydractinia echinata*, enlarged, showing three laminæ (l, l', l'') with their interlaminar spaces (*i i*), and a single spine (*s*). [Copied from Carter.]

Fig. 5.—Part of a vertical section of *H. echinata*, enlarged 90 times. Showing the radial pillars (*p p*) and the connecting-processes or concentric laminæ (*c c*), with the intervening interlaminar spaces.

Fig. 6.—Spine of *Hydractinia echinata*, greatly enlarged.

Fig. 7.—*Hydractinia circumvestiens*, S. V. Wood, Red Crag, Suffolk. Vertical fracture of the skeleton, enlarged 3 times, showing the zoöidal tubes (*t t*) and the rows of chambers representing the interlaminar spaces.

Fig. 8.—Part of the surface of a worn example of the same, enlarged, showing the large perforated radial pillars (*p*) and the mouths of the zoöidal tubes.

Fig. 9.—Surface of an unworn example of the same, enlarged 24 times, showing the large perforated pillars (*p*), the surface-tubercles representing the small radial pillars (*b b*), the astrorhizal grooves (*g*), and the zoöidal apertures (*t*).

Fig. 10.—Portion of the same, further enlarged. These two figures are from a beautiful specimen of *H. circumvestiens* in the British Museum, and were kindly drawn for me by Mr. Arthur H. Foord.

Fig. 11.—Vertical section of *H. circumvestiens*, enlarged 12 times, showing the zoöidal tubes (*t t*), the irregular interlaminar chambers (*i i*), and the large radial pillars (*p p*). These last have their axes traversed by irregular canals, giving them a cribriform structure.

Fig. 12.—Tangential section of the same, similarly enlarged, showing the transversely divided radial pillars and zoöidal tubes.

Fig. 13.—Part of the last section, enlarged 24 times, showing the apparent composition of the skeleton out of irregular calcareous granules.

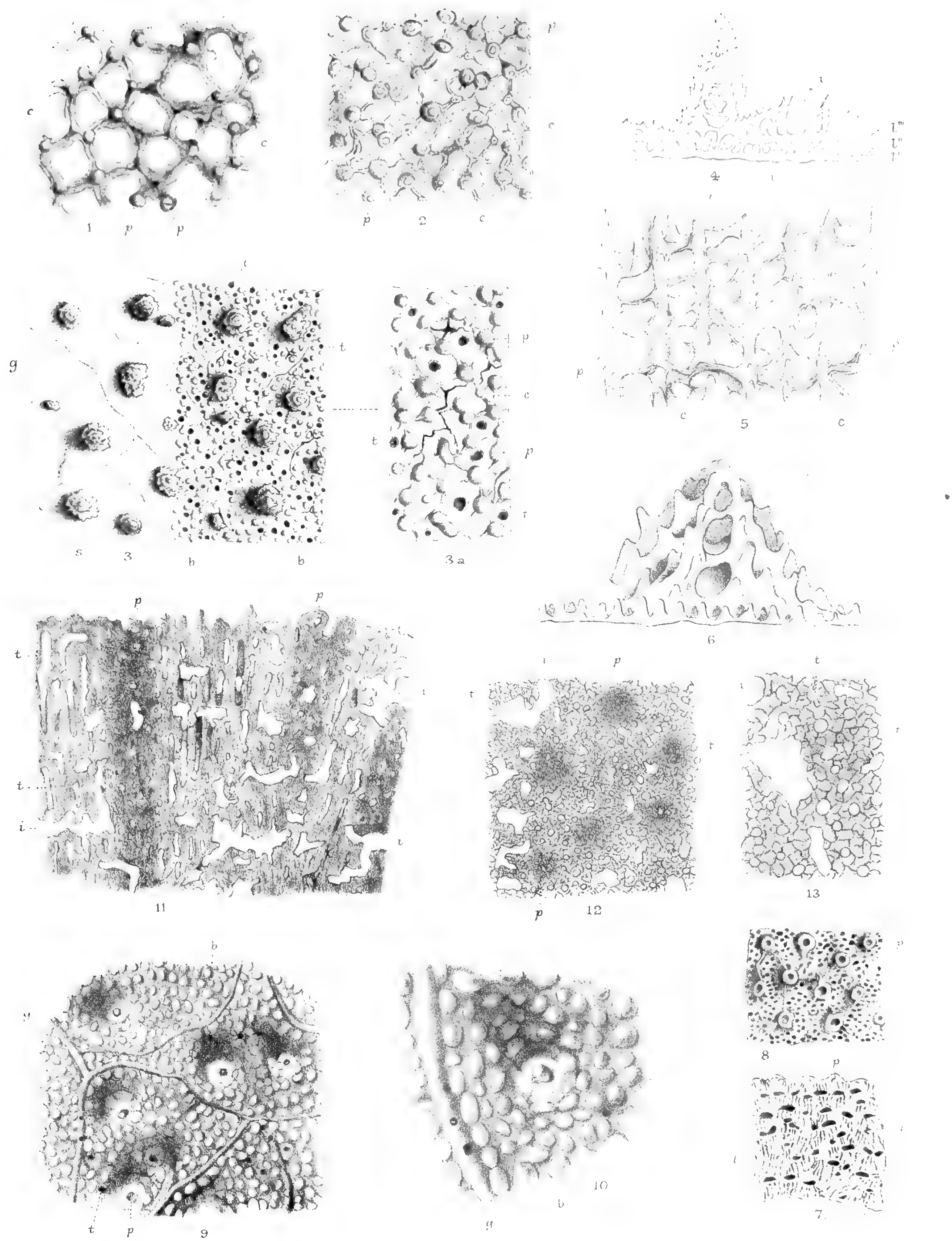

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PLATE VII.

Fig. 1.—*Stromatopora discoidea,* Lonsd.; tangential section, enlarged 12 times. Wenlock Limestone, Ironbridge.

Fig. 2.—Vertical section of the same, similarly enlarged, showing the minute tabulate zoöidal tubes. A single latilamina alone is shown.

Fig. 3.—*Stromatoporella eifeliensis,* n. sp.; tangential section, enlarged 12 times. *c c,* astrorhizal canals crossed by " astrorhizal tabulæ."

Fig. 4.—Vertical section of the same, similarly enlarged. *c c,* Cut ends of the astrorhizal canals, showing the astrorhizal tabulæ. The general structure of the skeleton in this form is very similar to that of *S. granulata,* Nich., but it seems to be sufficiently separated from the latter by the great development of the astrorhizal system and by other minor characters.

Fig. 5. *Stromatoporella granulata,* Nich.; tangential section, enlarged 12 times. Devonian (Hamilton Formation), Arkona, Ontario.

Fig. 6.—Vertical section of the same, similarly enlarged.

Fig. 7.—*Stylodictyon columnare,* Nich.; a fragment, of the natural size, showing a vertical polished section. Devonian (Corniferous Limestone), Sandusky, Ohio.

Fig. 8.—Upper surface of the preceding specimen, of the natural size.

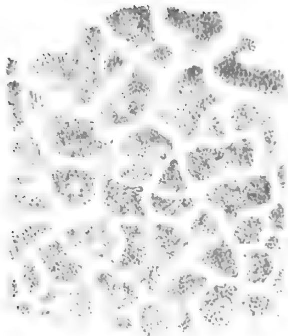
Fig. 9.—Vertical section of the same, enlarged 5 times.

Fig. 10.—Tangential section of the same, enlarged 12 times. The portion figured exhibits the centre of an astrorhiza.

Fig. 11.—Vertical section of the same, enlarged 12 times, embracing one of the intervals between a pair of the vertical columns.

Fig. 12.—*Rosenella macrocystis,* Nich; vertical section enlarged 12 times. Wenlock Limestone, Wisby, Gotland. [Coll. Dr. George J. Hinde.]

Fig. 13.—Tangential section of the same, similarly enlarged.



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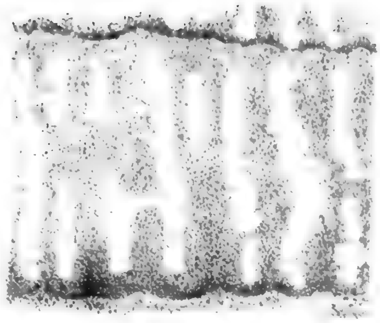

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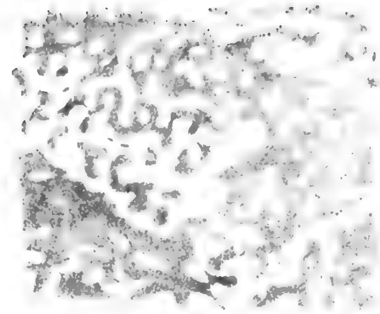

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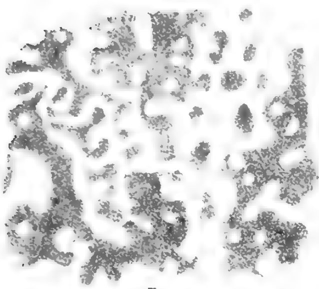

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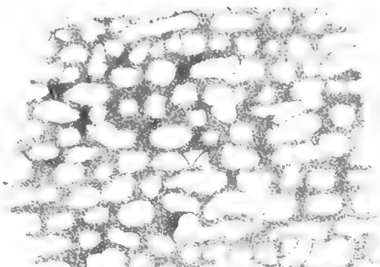

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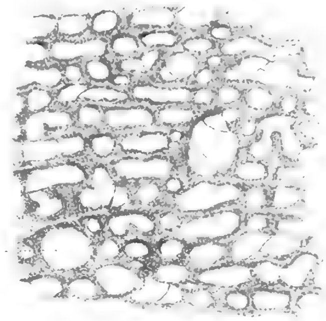

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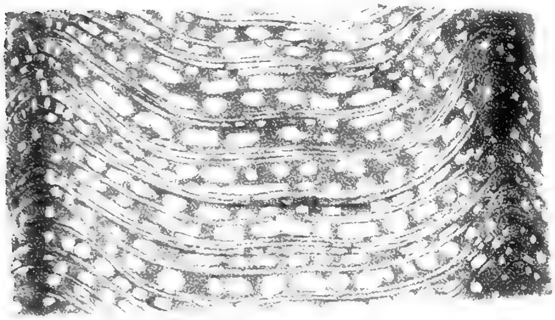

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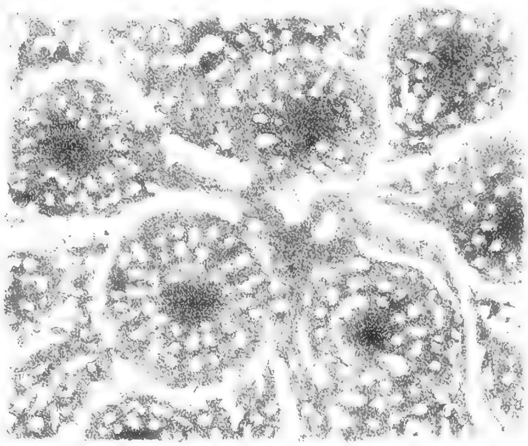

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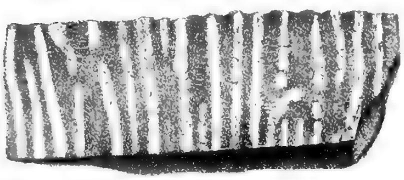

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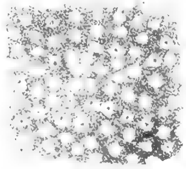

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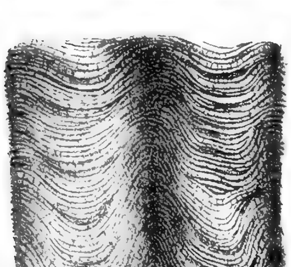

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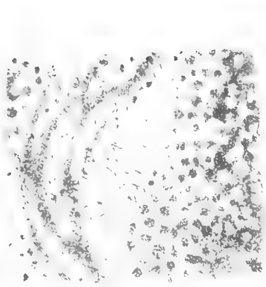

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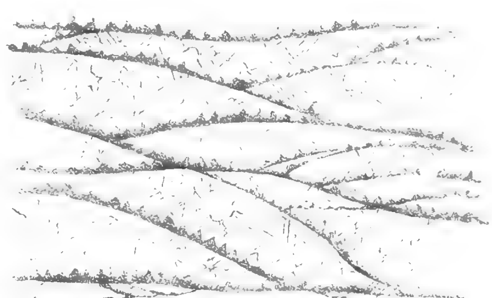

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PLATE VIII.

Fig. 1.—*Beatricea nodulosa*, Bill.; a fragment from the Cincinnati Group of Marion County, Kentucky. Of the natural size.

Fig. 2.—Transverse section of the same, enlarged twice.

Fig. 3.—Vertical section of the same, enlarged twice.

Fig. 4.—Part of a transverse section of another specimen of the same species, enlarged 12 times. Hudson River Group, West-End Lighthouse, Anticosti. [Collected by Mr. Richardson, Canad. Geol. Survey.] The section shows radial pillars, similar to those of *Labechia*, traversing the vesicular tissue.

Fig. 5.—Part of the preceding section, enlarged 24 times. In the interior of the vesicles the granular calcareous matter is so disposed as to leave clear vertical linear spaces.

Fig. 6.—Part of the periphery of a very large specimen of the same, in transverse section, enlarged 6 times, showing radial pillars and concentric laminæ. In parts of the section the ordinary lenticular vesicles characteristic of *Beatricea* are preserved. Hudson River Group, West-End Lighthouse, Anticosti. [Collected by Mr. Webster, Canad. Geol. Survey.]

Fig 7.—Part of a tangential section of the preceding specimen, enlarged 6 times.

Fig. 8.—Portion of the surface of the same specimen, enlarged 6 times, showing different-sized apertures, the larger of which are disposed in indistinctly spiral rows.

Fig. 9.—*Stachyodes verticillata*, McCoy, sp. (= *S. ramosa*, Barg.); a fragment, the natural size. Devonian, Hebborn (Paffrath district).

Fig. 10.—Longitudinal section of another specimen of the same, from the same locality, enlarged twice, showing the axial tabulate tube, the growth of the skeleton by successive convex layers, and the radiating zoöidal tubes. [For the sake of clearness, the zoöidal tubes are placed rather farther apart than they should be in a figure drawn strictly to the scale of two diameters.]

Fig. 11.—Transverse section of the same, enlarged twice.

Fig. 12.—Surface of the same, enlarged 6 times, showing the apertures of the zoöidal tubes. The lower part of the figure shows these openings concealed by a thin calcareous membrane.

Fig. 13.—Small portion of the tangential section of the same, enlarged 12 times, showing the minutely tubulated character of the skeleton-fibre. Owing to the direction of the tubuli, they are necessarily cut across transversely in a tangential section.

Fig. 14.—Part of a longitudinal section of the same, showing the zoöidal tubes, and the minute tubuli running parallel with these, enlarged 12 times. In this preparation the minute tubuli above spoken of are injected with some opaque material.

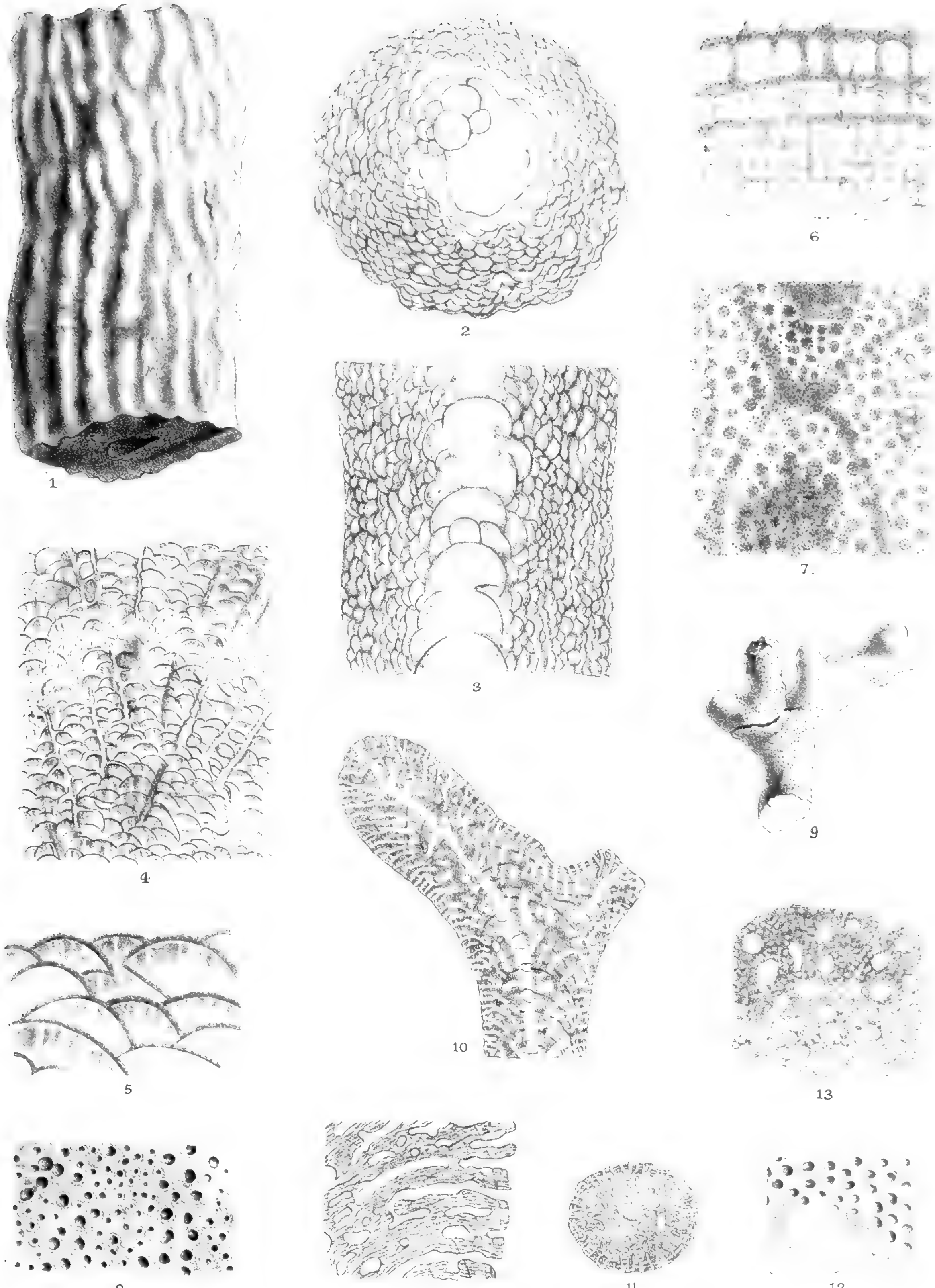

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PLATE IX.

Fig. 1.—A fragment of limestone from the "*Ramosa*-Bänke" of Schulz, Middle Devonian, Hebborn, Paffrath district, natural size. The rock is almost wholly composed of the broken stems of *Amphipora ramosa*, Phill., sp., some being covered with a thin imperforate membrane, while others have a vermiculate or tuberculated exterior.

Fig. 2.—Longitudinal section of a stem of *Amphipora ramosa*, Phill., sp., enlarged 12 times, showing the axial tube and the large marginal vesicles, with the intermediate reticulated tissue. Hebborn.

Fig. 3.—Transverse section of the same, similarly enlarged.

Fig. 4.—Longitudinal section of another specimen of the same, from the same locality, enlarged 8 times. In this specimen marginal vesicles are not developed, and the axial canal is intersected by well-developed tabulæ.

Fig. 5.—Part of the longitudinal section of the cœnosteum of the recent *Distichopora coccinea*, Gray, taken in the plane of the zoöidal tubes, showing the cœnenchymal canal-system, enlarged 12 times.

Fig. 6.—Portion of a mass of *Idiostroma Roemeri*, n. sp., from the Devonian Limestone of Hebborn (Paffrath district), of the natural size.

Fig. 7.—Transverse section of one of the cylindrical stems of the same, enlarged twice, showing the axial tube and the tabulate zoöidal tubes.

Fig. 8.—Longitudinal section of the same, enlarged twice, showing the axial tube with its funnel-shaped tabulæ and its lateral branches. The section traverses a second smaller longitudinal tube running parallel with the main one.

Fig. 9.—Part of the surface of the same, enlarged, showing the vermiculate ridges and the apertures of the zoöidal tubes.

Fig. 10.—Tangential section of the same, enlarged 12 times.

Fig. 11.—Part of the outer zone of a transverse section of the same, enlarged 12 times, showing the tabulate zoöidal tubes.

PLATE IX.

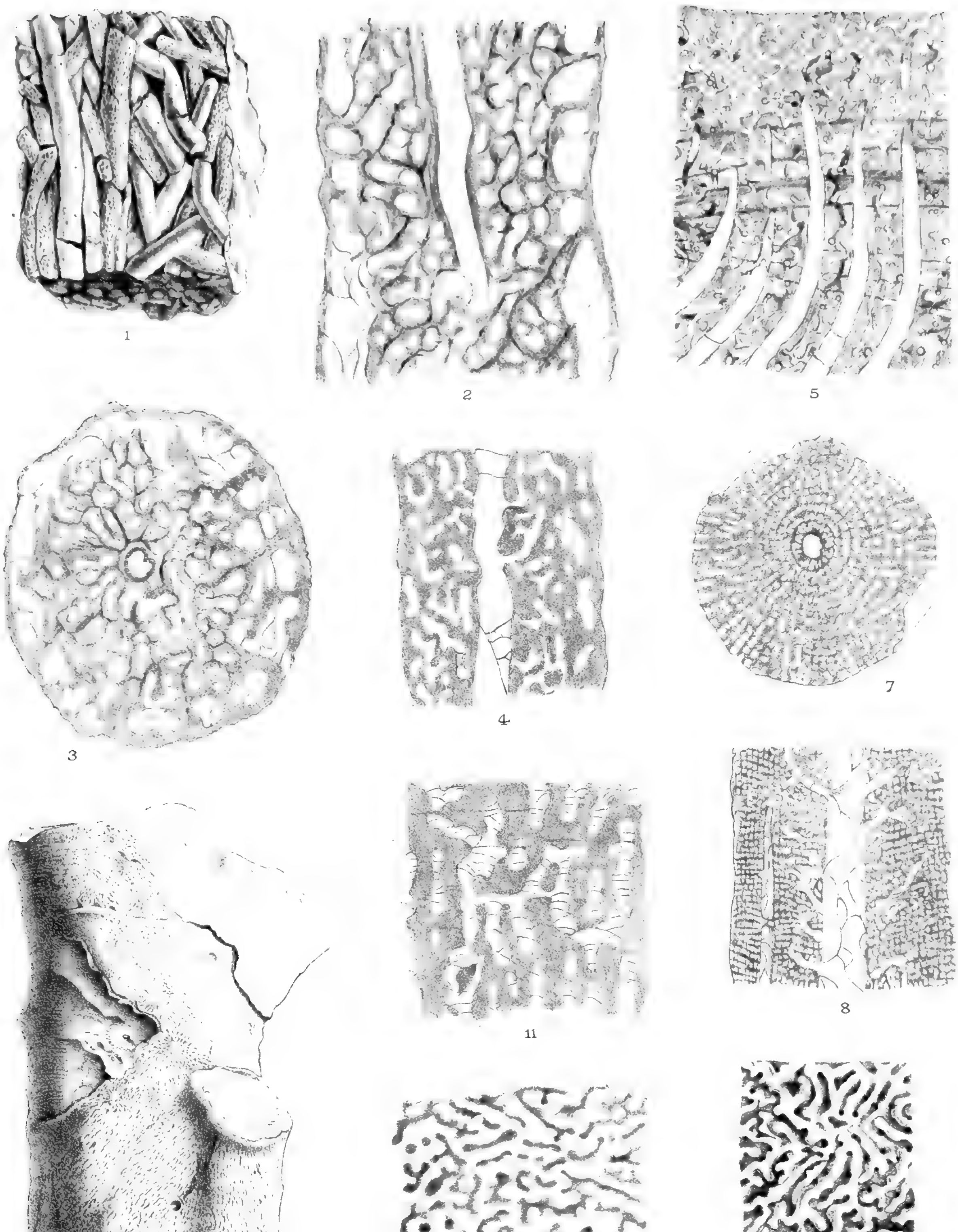

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PLATE X.

Fig. 1.—*Stromatoporella laminata*, Barg., sp. (= *Diapora laminata*, Barg.). Tangential section, enlarged 12 times. Middle Devonian, Büchel (Paffrath district).

Fig. 2.—Vertical section of the same, similarly enlarged. The funnel-shaped tabulæ of the " *Caunopora*-tubes " are well shown.

Fig. 3.—Part of the surface of an unworn specimen of the same, enlarged 3 times, showing the mouths of the " *Caunopora*-tubes," connected here and there by horizontal stolons. Büchel.

Fig. 4.—Part of the surface of another beautifully preserved example of the same, from the same locality, enlarged 12 times, showing that the surface-tubercles are perforated by circular apertures at their summits.

Fig. 5.—*Stromatopora bücheliensis*, Barg., sp.; part of a dendroid example, of the natural size, from the Middle Devonian of Büchel. This is the *Caunopora bücheliensis* of Bargatzky, and is not uncommon in the Devonian of both Britain and Germany, occurring both with and without the " *Caunopora*-tubes," which are present in the specimen figured.

Fig. 6.—Tangential section of the same specimen, enlarged 12 times.

Fig. 7.—Vertical section of the same specimen, similarly enlarged.

Fig. 8.—*Stromatopora Hüpschii*, Barg., sp.; tangential section, enlarged 12 times. Middle Devonian, Büchel. This is the *Caunopora Hüpschii* of Bargatzky. It occurs in the Middle Devonian of both Britain and Germany, sometimes with and sometimes without the " *Caunopora*-tubes," which are present in the specimen figured.

Fig. 9.—Vertical section of the same specimen, enlarged 12 times. The section cuts through one of the " *Caunopora*-tubes," with its funnel-shaped tabulæ, and also divides transversely two of the horizontal connecting-tubes belonging to the same system.

Fig. 10.—Small portion of a polished specimen of *Stromatopora Beuthii*, Barg. (?), of the natural size, from the Devonian Limestone, Teignmouth. In this specimen the " *Caunopora*-tubes " are of exceptionally large size.

Fig. 11.—Tangential section of the preceding, enlarged 12 times. The specimen, like many of those from South Devon, and particularly those found in the pebbles of the Triassic conglomerates, has undergone much crystallisation and squeezing. The " *Caunopora*-tubes," as is commonly the case, have their cavities largely filled up with a deposit of light-coloured sclerenchyma.

Fig. 12.—Vertical section of the same, enlarged 12 times. The minute structure of the skeleton is considerably altered and distorted by crystallisation and pressure.

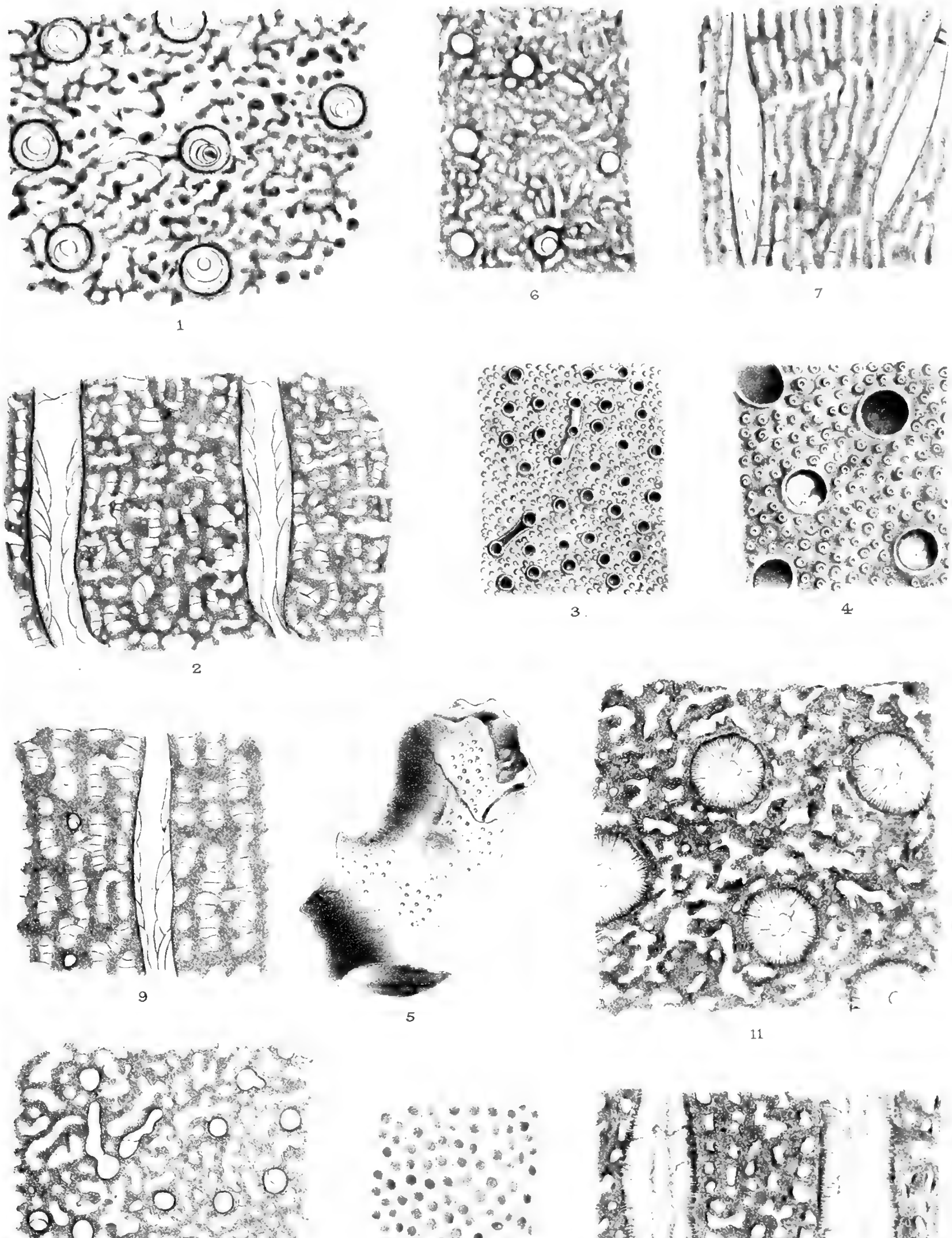

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PLATE XI.

Fig. 1.—Vertical section of *Stromatoporella eifeliensis*, n. sp., enlarged 24 times, showing the minute tubuli occupying the axes of the pillars and concentric laminæ. Middle Devonian, Gerolstein.

Fig. 2.—Tangential section of the same, similarly enlarged, showing the system of minute branching tubuli in the substance of the skeleton-fibre. The section traverses part of an astrorhizal system.

Fig. 3.—Vertical section of *Stromatoporella*, sp., enlarged 50 times, showing the minute tubulation of the skeleton-fibre. Middle Devonian, Gerolstein. This species is peculiar in having the interlaminar spaces crossed by innumerable vesicular tabulæ.

Fig. 4.—Tangential section of the same, similarly enlarged.

Fig. 5.—Tangential section of *Stachyodes verticillata*, M'Coy, sp., enlarged 24 times, showing the tubuli of the skeleton-fibre filled with opaque matter. Devonian, Teignmouth.

Fig. 6.—Part of a tangential section of another specimen of the same, from the Middle Devonian of Hebborn (Paffrath district), in which the tubuli of the skeleton-fibre are filled with transparent calcite. Enlarged 24 times.

Fig. 7.—Part of the tangential section of *Idiostroma?* sp. (? = *Stromatopora capitata*, Goldf.), enlarged 24 times, showing numerous dark rounded spots in the interior of the transparent skeleton-fibre. Middle Devonian, Hebborn.

Fig. 8.—Vertical section of the same, similarly enlarged, showing two radial pillars and the intervening tabulate zoöidal tubes. Dark rod-like tracts and lines are seen in the interior of the skeleton-fibre.

Fig. 9.—Part of a tangential section of the original specimen of *Parallelopora Goldfussi*, Barg., enlarged 24 times. The skeleton-fibre is in the main opaque, but exhibits in its interior numerous clear round spots or vacuities filled with transparent calcite. Middle Devonian, Hand (Paffrath district).

Fig. 10.—Part of a tangential section of *Stromatoporella* (*Diapora*) *laminata*, Barg., enlarged 24 times, showing the porous skeleton-fibre. Middle Devonian, Büchel.

Fig. 11.—Tangential section of *Syringostroma? ristigouchense*, Spencer, sp., enlarged 12 times. Upper Silurian, Ristigouche. (From a specimen presented to the writer by Professor Spencer.) The section shows that the skeleton-fibre has the porous structure of that of the *Stromatoporidæ*, while the large radial pillars with their radiating connecting-processes are arranged as in the genus *Actinostroma*.

Fig. 12.—Vertical section of the same, similarly enlarged, showing the porous skeleton-fibre, the large radial pillars, and the regularly-developed horizontal "arms."

Fig. 13.—Tangential section of the original specimen of *Syringostroma densum*, Nich., enlarged twelve times, showing the porous structure of the skeleton-fibre and its generally reticulated character. The cut ends of a number of large-sized radial pillars are also shown. Devonian (Corniferous Limestone), Ohio.

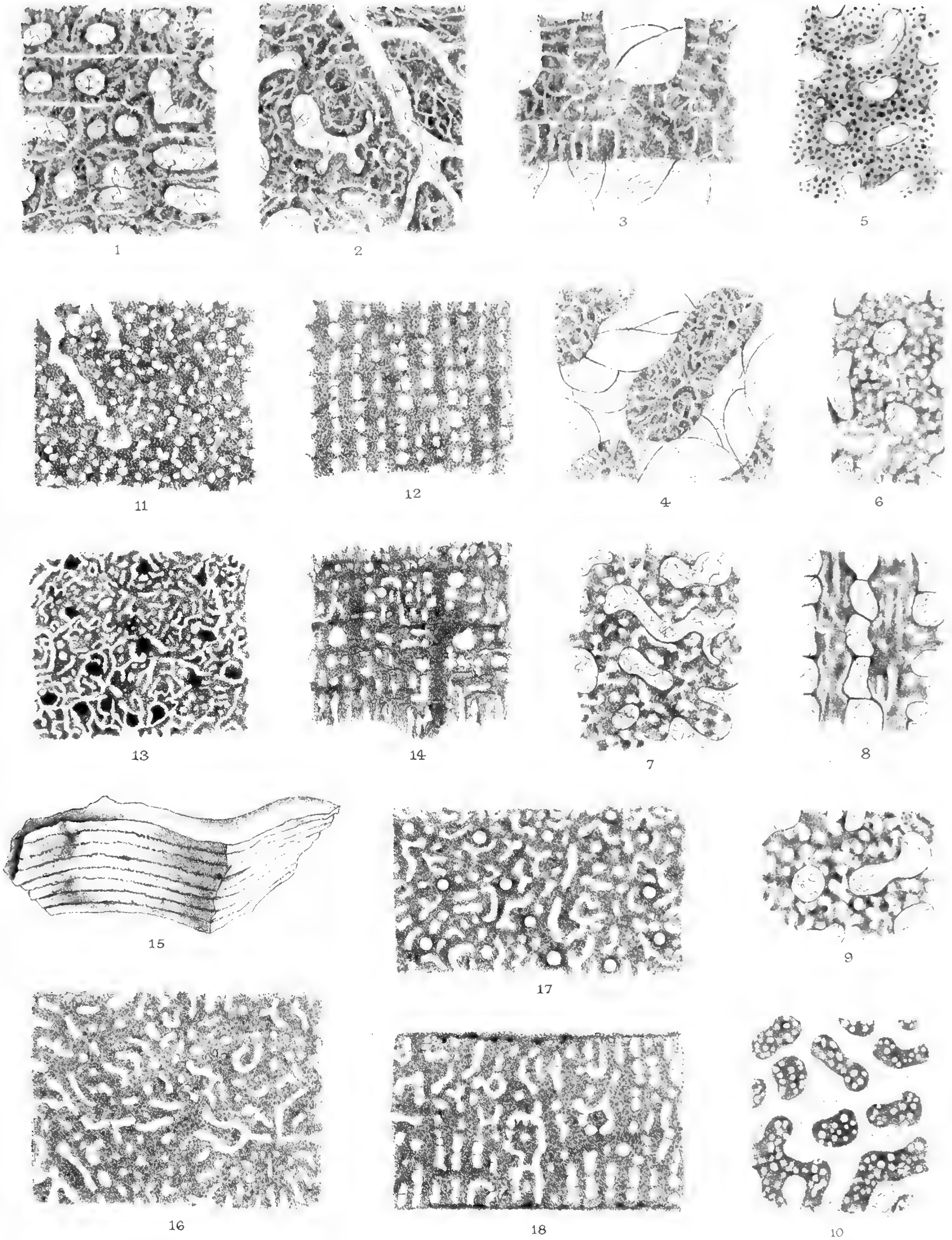
Fig. 14.—Vertical section of the same, similarly enlarged.

Fig. 15.—A small fragment of *Stromatopora concentrica*, Goldf., from the Middle Devonian of Gerolstein, of the natural size. The specimen, both as regards general structure and mode of preservation, is absolutely identical with the original example of the species figured in the 'Petrefacta Germaniæ.'

Fig. 16.—Tangential section of the same, enlarged 12 times, showing the porous and reticulated character of the skeletal tissue.

Fig. 17.—Tangential section of another specimen of the same, in the "*Caunopora*-state." The "*Caunopora*-tubes" are exceedingly minute and very regularly placed, but have all the characters of the tubes of "*Caunopora*" generally. They are much smaller than the tubes of any known species of *Aulopora* or *Syringopora* in the Devonian Series.

Fig. 18.—Vertical section of the same, enlarged 12 times, showing the irregular, tabulate zoöidal tubes. The portion figured embraces the thickness of a single "latilamina."



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THE

PALÆONTOGRAPHICAL SOCIETY.

INSTITUTED MDCCCXLVII.

LONDON:

MDCCCLXXXVI.

*** The exhaustive Monograph on the British Fossil Brachiopoda, of which the present Volume is the last portion, was the result of investigations extending over thirty years. Its author, Dr. T. DAVIDSON, spared neither trouble nor expense in its production, and placed on the lithographic stone with his own hand the Drawings depicted in two hundred and twenty-nine of the Plates employed for the illustration of the first five Volumes. While the accompanying Bibliography (towards the compilation of which Mr. W. H. Dalton had rendered most valuable assistance) was in the press, an unexpected illness caused the active pen to rest, and brought Dr. T. Davidson's life to a close.

T. W.

2nd January, 1886.

A MONOGRAPH

OF THE

BRITISH FOSSIL BRACHIOPODA.

BIBLIOGRAPHY OF THE BRACHIOPODA

BY THE LATE

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AND

W. H. DALTON, F.G.S.,

LATE OF H.M. GEOLOGICAL SURVEY.

VOL. VI.

LONDON:

PRINTED FOR THE PALÆONTOGRAPHICAL SOCIETY.

1886.

PRINTED BY
J. E. ADLARD, BARTHOLOMEW CLOSE.

PREFACE.

No one can be more sensible than the compilers of this list how far it falls short of its original aim, a record of all works touching upon Brachiopoda. Besides the literature of existing species there is scarcely a paper dealing with Palæozoic or Secondary Rocks that does not incidentally mention the occurrence of Brachiopoda, but such only are here entered as show this by the title, or have been seen by some of our contributors. To pervade the entire mass of geological literature in search of such references would occupy many years of unremitting labour, and would, further, produce too cumbrous a list to be of service to the student with limited leisure.

We believe that the present list includes every work of importance, and that additions will be only of future publications or of works containing mere casual references to Brachiopoda. We have derived considerable assistance from the 'Catalogue of Scientific Papers,' edited by the Royal Society, but have been careful to avoid such faults as there are in that valuable compilation, viz. the misleading repetition of works of joint authorship (without indication of priority of names in original text), the absence of the series-numbers (an essential part of many references), and incorrect dates. In the last matter we have doubtless made many errors ourselves, for the actual date of publication being usually lost in binding serials, the date of reading, or the year of completion of the volume alone remains in many cases, neither being the true date. Precision in this respect, however, cannot be always attained, some publishers ante-dating and others post-dating the works they issue.

In conclusion we beg to thank those who have assisted us in our work, especially Dr. L. G. de Koninck, M. G. Dewalque, M. P. de Loriol, M. T. Lefevre, Mr. S. A. Miller, Prof. J. Hall, and others.[1]

[1] A portion of this list of works was published by one of us in the 'Annales de la Société Malacologique de Belgique,' tome xii, 1877.

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PRINTED BY J. E. ADLARD, BARTHOLOMEW CLOSE.

THE

PALÆONTOGRAPHICAL SOCIETY.

INSTITUTED MDCCCXLVII.

LONDON:

MDCCCLXXVIII—MDCCCLXXXVI.

THE LIAS AMMONITES.

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49—164	IX—XVIII	1879	May, 1879
165—264	XIX—XXII	1880	May, 1880
	XXIIA—XXIIB	1881	May, 1881
	XXIII—XL	1880	May, 1880
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329—400	XLIX—LII, LIIA, LIII—LXIX	1882	June, 1882
401—440	LXX—LXXVII	1883	October, 1883
441—480	LXXVIII—LXXXVII	1884	December, 1884
481—503	LXXXVIII	1885	January, 1886

MONOGRAPH

ON THE

LIAS AMMONITES

OF

THE BRITISH ISLANDS.

BY THE LATE

THOMAS WRIGHT, M.D., F.R.S., F.G.S.,

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LONDON:

PRINTED FOR THE PALÆONTOGRAPHICAL SOCIETY.

1878—1886.

⁂ This Monograph on the Lias Ammonites (a memorial of the ability of its pains-taking Author, and representing the desire of a life) possesses a melancholy interest. Commenced in 1878, and continued year by year until only a few pages remained unprinted, its further progress was, in 1884, stayed by the hand of death. Sufficient notes, however, were in existence to complete the work, and with these it is offered in its present form.

THOS. WILTSHIRE.

2nd January, 1886.

PRINTED BY
J. E. ADLARD, BARTHOLOMEW CLOSE.

STEPHANOCERAS CRASSUM, *Young and Bird.* Pl. LXXXVI, figs. 1, 2, 8—10.

AMMONITES CRASSUS, *Young and Bird.* Geol. Survey Yorkshire Coast, p. 253, 1822.
— — *Phillips.* Geology of Yorkshire, pl. xii, fig. 15, 1829.
— — *Simpson.* Monogr. on Ammonites, p. 20, 1843.
— — *Quenstedt.* Cephalopoden, p 174, tab. xiii, fig. 10, 1846.
— — — Der Jura, p. 251, tab. xxxvi, fig. 1, 1858.

Diagnosis.—Shell discoidal, whorls subquadrate, depressed, and slightly involute; shell thick, with a circle of spiny tubercles on the margin of the siphonal area, sides ornamented with thirty-four costæ, which commence near the umbilicus and extend to the tubercle, where each bifurcates and sends two branches across the area to unite with their fellows on the opposite side; aperture subquadrate, slightly grooved below to receive the return of the spire.

Dimensions.—Transverse diameter 75 millimètres; height of last whorl 20 millimètres; width of umbilicus 42 millimètres; height of aperture 20 millimètres; width of aperture 22 millimètres.

Description.—This shell exhibits similar characters to *Stephanoceras commune*, but is a much thicker and more robust cephalopod with a deeper umbilicus. The costæ between the umbilicus and the tubercles are rather irregular, some are bent, others straight, and the circle of spiny tubercles around the margin of the siphonal area gives this variety a crown-like form. I have figured (Pl. LXXXVI, figs. 1, 2) a variety which closely resembles one of the varieties of *Steph. fibulatum*, and is usually collected from the same shaly beds of the Upper Lias.

ADDENDA.

LYTOCERAS JURENSE,[1] *Zieten.* Pl. LXXIX.

The very fine fossil so beautifully delineated two thirds the natural size in this Plate, was presented several years ago to the Museum of the Royal School of Mines by the Earl of Enniskillen, F.R.S. The locality is not recorded, but I have no doubt after an examination of the matrix that it was obtained from the Lyt.-Jurense-zone of Dorsetshire. The shell is preserved, and shows all the delicate sigmoidal curves it formed during growth. This specimen I met with accidentally in one of the wall cases of the top gallery of the

[1] See p. 413.

museum, when searching for another Ammonite. The fossil is one of the finest examples of this grand species extant, and shows the remarkable flattening-in of the spiral margin of the whorl where it encircles the umbilicus; the same specific character is displayed even more perfectly in the beautiful little mould of this species figured in Pl. LXXIV, figs. 3—5. The Earl of Enniskillen's specimen was not known to me when Pl. LXXIV was drawn, and the German mould being at that time the best example I could figure, it was given as a type. My description of the species had been written for a considerable time before this giant *Lytoceras Jurense* was found, so that I was unable to do more than give the reference to Pl. LXXIV on p. 413.

Amaltheus lenticularis, *Young and Bird.* Pl. LXXXII, figs. 14 and 15.

Ammonites lenticularis, *Young and Bird.* Geol. Surv. Yorkshire, p. 269, 1828.
— — *Simpson.* Monogr. on Ammonites, p. 37, 1843.
— — — Fossils of Yorksh. Lias, p. 79, 1855.
Amaltheus Engelhardtii, *Tate and Blake.* Yorkshire Lias, p. 294, 1876.

Diagnosis.—Shell much compressed; inner whorls nearly concealed, outer whorl one half the diameter of the disc; sides slightly convex; siphonal area very thin, forming a sharp, feebly crenulated edge at the border; umbilicus narrow, with upright walls; sides covered with fine transverse striæ, slightly bent; beneath the transverse radii four or five longitudinal obsolete lines; aperture narrow and acutely triangular.

Dimensions.—Transverse diameter 73 millimètres; height of aperture 40 millimètres; transverse diameter at base 12 millimètres; width of umbilicus 13 millimètres.

Description.—The rare example of *Amaltheus lenticularis*, Young, now for the first time figured, shows very clearly the flat, involute, obsoletely-radiated, longitudinally-striated, sharp-pointed character of the species, which is a rare form in the Yorkshire Lias and of which Mr. Young[1] says:—"The last shell of this family which we shall name is more lenticular than any that we have seen. The exterior part of the whorl runs to a thin edge, plain or very faintly crenated; the sides are smooth, or marked with very faint undulating lines; the central part is an umbilicus, with upright sides, the inner whorls being scarcely visible, and the aperture forms a triangle, of which the outer angle is extremely acute, owing to the thinness of the edge. This rare species, found in the Lias bands, may fitly be termed *Ammonites lenticularis.*" The authors of the 'Yorkshire Lias' regard this Ammonite as a form of *Amaltheus Engelhardti*, but with this view I cannot agree.

The beautiful specimen I have figured was presented by my old friend, the late Mr.

[1] 'Geological Survey of the Yorkshire Coast,' 2nd ed., pp. 268, 269, 1828.

John Leckenby, F.G.S., of Scarborough, to the Royal School of Mines Museum, London, as a very good type of a rare Yorkshire species.

Locality and Stratigraphical Position.—*Amaltheus lenticularis* is found in the zone of *Amaltheus spinatus* in the rich Ironstone beds at Eston, and Upleatham, near Saltburn, also at Hawsker. I am indebted to my friend Mr. E. T. Newton, F.G.S., Palæontologist to the Geological Survey, for calling my attention to this specimen now figured for the first time.

In the preceding portions of the Monograph[1] I have referred to the remarkable curved plates, sometimes calcareous and sometimes horny, occasionally found in position within the shell of the Ammonite, and I have drawn attention to the fact that the distinctive character of the structure of the plates is associated with modifications of the septa and of the general ornamentation of the shell, as well as with geological position. Since these remarks were in type, I have had drawn on Plate LXXXVIII four specimens derived from the Oolitic and Liassic beds, which may be taken as representatives of the calcareous and divided forms (*Aptychi*) and of the horny and undivided ones (*Anaptychi*).

Figure 1 of Plate LXXXVIII represents an almost perfect *Aptychus* from the upper beds of the Inferior Oolite of Leckhampton Hill. It consists of thin shelly laminæ, exhibiting lines of growth, and is in length 140 millimètres and in breadth 95. I imagine it must have belonged to *Cosmoceras Parkinsoni*. In my cabinet is an example of this species from the upper beds of the Inferior Oolite at Halfway House, near Yeovil. The specimen is 500 millimètres in diameter, and has its last chamber transversely fractured, the curve and size of which agrees very nearly with that of the *Aptychus*.

Figure 2 is a drawing of an *Anaptychus*, which I dislodged from the outer chamber of a large *Arietites stellaris*, taken out of the Lower Lias strata of Charmouth. This body is bell-shaped, corneous, highly undulated on the surface and displays the lines of growth. It is difficult to understand how bodies so irregular, as are many of the *Anaptychi*, could have fitted the internal surface of the final chamber.

Figure 3, from the British Museum, but without locality, is another of the bell-shaped *Anaptychi*. It has a thickened central column and lateral biflexed undulations passing off on each side. The upper part of the body runs out into a pear-shaped process.

Figure 4 is also from the British Museum, but has no label of locality. The fossil appears to have been in its original condition a symmetrical structure, and resembled in

[1] Pp. 182—185, general statement; p. 269, account of forms belonging to *Arietites;* p. 307, to *Aegoceras;* p. 383, to *Amaltheus;* p. 430, to *Harpoceras;* p. 472, to *Stephanoceras.*

some degree a horse's hoof. Around its convex border, and within each half of the body as well as towards the two projecting terminations, there are traces of a muscular attachment. This *Anaptychus* is another of the bell-shaped type. Its figure reminds me of a very fine *Anaptychus* contained in the body chamber of a large *Arietites Bucklandi*, which had been used in building a part of the Bath Station, and which I saw protruding from the stone the last time I visited that city.

The lists of British fossils given in my account of the Zones of the Lias Formation (pp. 14—149), and derived from the Memoirs of various authors, contain references to a few species of Ammonites not figured by me. The omission has arisen from the fact that these forms have not come before my notice in any of the English museums or private cabinets I have investigated. In all probability the identification of the Ammonites in question with foreign species was not perfectly accurate.

INDEX TO THE GENERA[1] AND SPECIES OF THE LIASSIC AMMONITES DESCRIBED IN THIS MONOGRAPH.

[1] The synonyms are printed in italics.

[2] Named on the plate *Aegoceras maculatum* in error.

[3] Termed *Aegoceras Liassicum* on pls. xv, figs. 1, 2, and xvi, and *Aegoceras tortile* on pl. xv, figs. 10—12.

[1] Named *Arietites denotatus* on explanation of pl. vi.

[1] Termed *Arietites nodulosus* on the explanation of plate vi.

[1] Named *Aegoceras Loscombi* on explanation of plate xxxix.

GENERAL INDEX.

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PLATE LXXXVIII.

Fig. 1. APTYCHUS. From the Inferior Oolite of Leckhampton Hill, of unusual size. Probably belonging to *Cosmoceras Parkinsoni*. My collection.

2. ANAPTYCHUS. Belonging to *Arietites stellaris*. Lower Lias of Charmouth. My collection.

3. — Perhaps belonging to *Arietites Conybeari*. Locality unknown. British Museum.

4. — Locality unknown. British Museum.

PLATE LXXXVIII

Fig. 1

Fig. 2

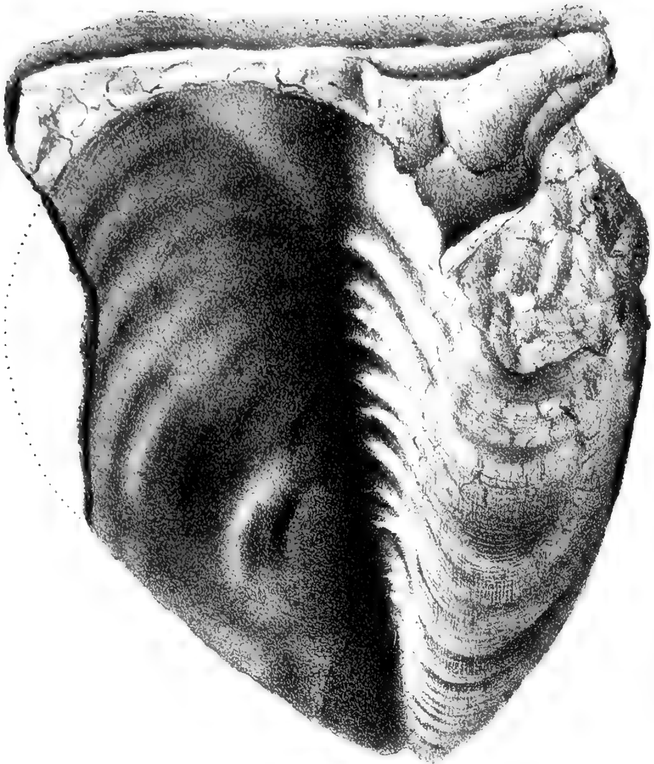


Fig. 3

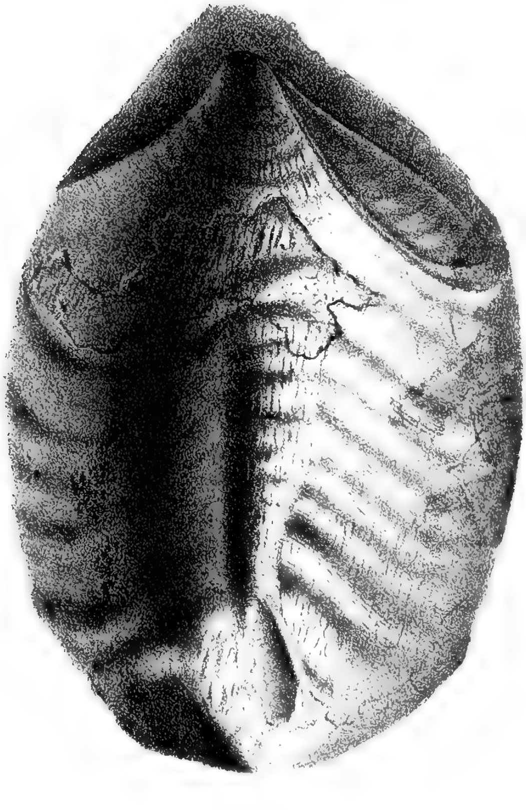
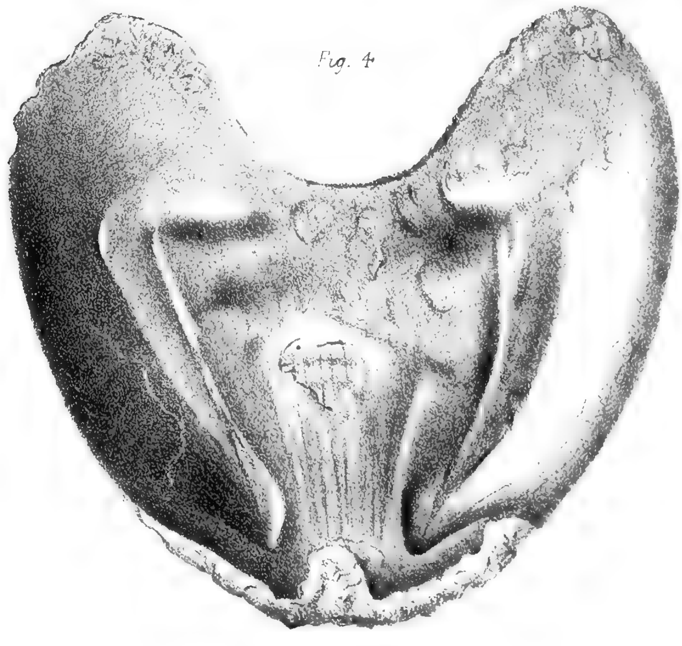


Fig. 4



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